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Dissolved Oxygen Measurements in Indiana Streams During Urban Runoff

Notre Dame Univ, Ind Dept of Civil Engineering

Prepared for

Municipal Environmental Research Lab, Cincinnati, Ohio Wastewater Research Div

Aug 78

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EPA-600/2-78-135
August 1978

DISSOLVED OXYGEN MEASUREMENTS IN INDIANA STREAMS DURING URBAN RUNOFF

by

Lloyd H. Ketchum, Jr.
University of Notre Dame
Notre Dame, Indiana 46556

Grant No. R805202-01

Project Officer

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OFFICE OF RESEARCH AND DEVELOPMENT
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16. ABSTRACT

This short term research project was undertaken for the purpose of locating and identifying sites where potential dissolved oxygen (D.O.) impacts exist during periods of urban runoff, and providing the necessary information to justify more extensive D.O. model verification studies at the impacted sites. Since there are little available field data on the effects of urban runoff on D.O. in receiving waters, this study was designed as a rough screening project to aid in selecting sites for potential in-depth study.

Twenty-five cities located in the state of Indiana were evaluated and D.O. measurements reported for nine of the sites thought to be most suitable for further monitoring. The project sampling program was designed to detect significant D.O. deficits in these streams during periods of rainfall and runoff. The results of the project indicate that wet weather D.O. levels generally appear to be similar or higher than those observed during dry weather conditions in the streams studied. Significant D.O. depletions were not observed and due to the screening nature of the sampling program, more subtle D.O. impacts could not be measured. Two cities, Bremen and Plymouth, are recommended as sites to conduct D.O. model verification studies.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Surface Water Runoff Combined Sewers Water Pollution *Water Quality	*Dissolved Oxygen	13 B

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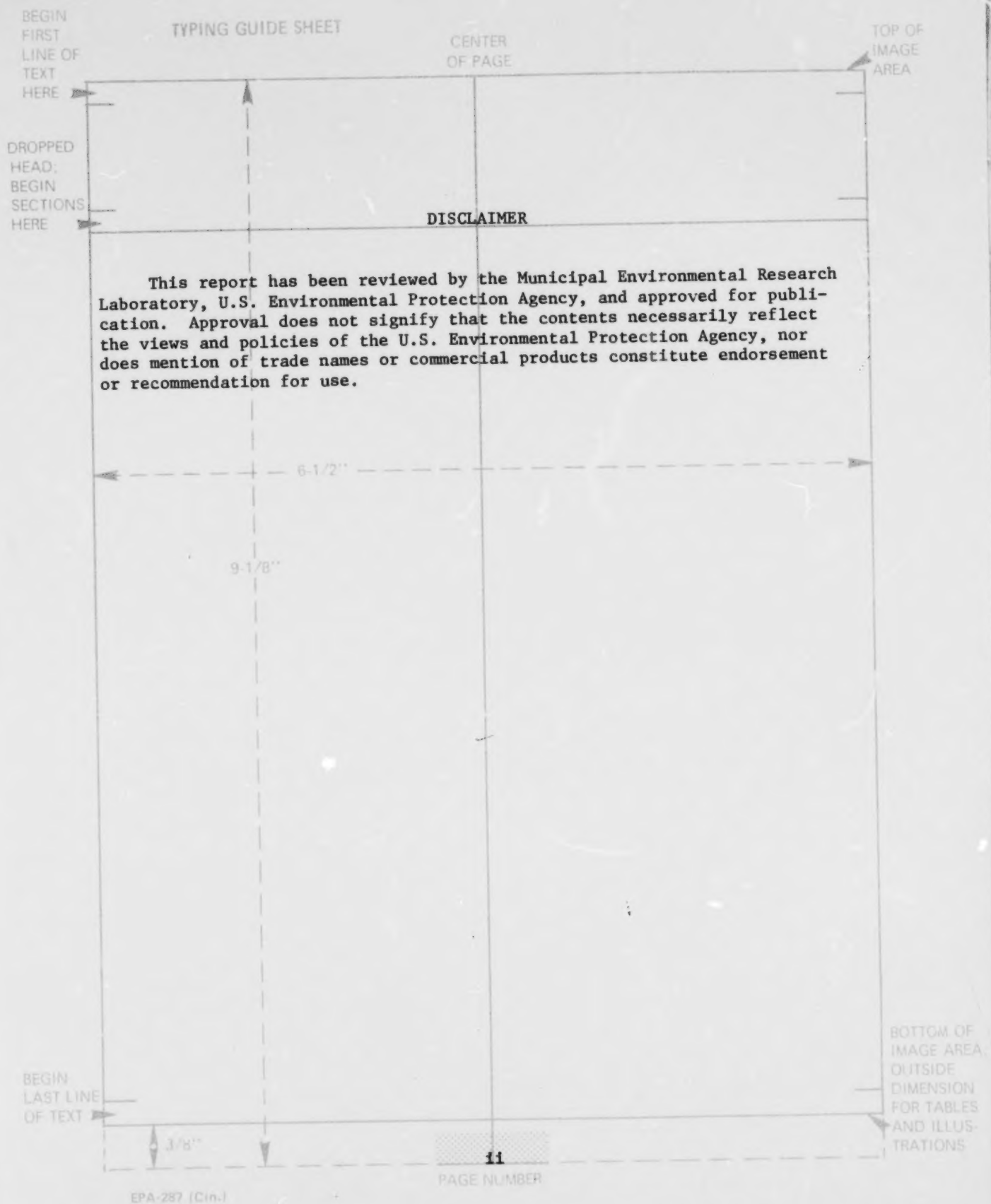

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FOREWORD

The Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testimony to the deterioration of our natural environment. The complexity of that environment and the interplay between its components require a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution and it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems for the prevention, treatment, and management of wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, for the preservation and treatment of public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research; a most vital communications link between the researcher and the user community.

This report describes the results of a short term screening project designed to identify potential stream sites at which more detailed studies of the impact of urban runoff on dissolved oxygen could be undertaken.

Francis T. Mayo, Director
Municipal Environmental Research
Laboratory

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ABSTRACT

This short term research project was undertaken for the purpose of locating and identifying sites where potential dissolved oxygen (D.O.) impacts exist during periods of urban runoff, and providing the necessary information to justify more extensive model verification studies at the impacted sites. Since there are little available field data on the effects of urban runoff on D.O. in receiving waters, this study was designed as a rough screening project to aid in selecting sites for in-depth study.

Twenty-five sites located in the state of Indiana were evaluated and D.O. measurements reported for nine of the sites thought to be most suitable for further monitoring. The project sampling program was designed to detect significant D.O. deficits in these streams during periods of rainfall and runoff. The results indicate that wet weather D.O. levels generally appear to be similar or higher than those observed during dry weather conditions in the streams studied. Significant D.O. depletions were not observed and due to the screening nature of the sampling program, more subtle D.O. impacts could not be measured. Two sites, Bremen, Indiana and Plymouth, Indiana, are recommended for additional in-depth studies.

This report was submitted in fulfillment of Grant No. R805202-01 by the Department of Civil Engineering at the University of Notre Dame under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period from March 28, 1977 to September 30, 1977, and the work was completed October 31, 1977.

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SECTION 1

INTRODUCTION

There is little nationally verified data on the environmental impacts of urban stormwater runoff on receiving waters. Impact data is needed to determine the degree of pollution in receiving waters caused during wet weather discharges particularly discharges from urban combined sewered areas. Priority should be given to sites that show a potential for a dissolved oxygen (D.O.) sag to occur as a result of combined sewer overflows (CSOs), and have receiving water characteristics that will enable field verification of unsteady state water quality prediction models.

The objective of this study was to locate and screen sites suitable for in-depth field monitoring studies to determine the D.O. impact of CSOs on receiving waters. The data collected during these proposed future in-depth field studies would be used for verifying and calibrating unsteady state water quality prediction models. The method used to select suitable sites was to first locate communities with combined sewer systems and then to measure changes in downstream D.O. concentration during periods of dry weather, during rainfalls, and shortly after rainfall periods. It was anticipated that D.O. sags would develop as a result of these combined sewer discharges and the relative magnitude of these sags would be used in evaluating the most suitable sites for the in-depth studies.

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SECTION 2

CONCLUSIONS AND RECOMMENDATIONS

Detrimental effects of combined sewer overflows on receiving streams cannot be determined by D.O. measurements alone. This is evidenced by the occurrence of D.O. concentrations frequently higher during wet weather conditions than during dry weather periods at the many locations monitored. D.O. deficits may have occurred during wet weather flows that could have been detected in more extensive and longer term sampling programs. However, no significant effects on D.O. that could be related to urban runoff were observed in the streams sampled during this screening study.

Two sites, Bremen, Indiana and Plymouth, Indiana, possess the characteristics which make them the most suitable of all sites studied for in-depth field studies. Both are on the same stream which has gaging stations located nearby, are served by combined sewers, can be easily accessed, and had no unusual features which would make the results peculiar to that site (e.g., pretreated by lagoons, flows over dams, downstream lakes). While neither site exhibited evidence of a significant D.O. impact, each site should be considered for study of other urban runoff impacts on receiving water quality.

Other advantages which favor selection of Bremen and Plymouth include long downstream distances without significant point discharges, and urban runoff volumes which make significant contributions to the stream flow. The stream length from Bremen (at the confluence of Armey Ditch and the Yellow River) downstream to Plymouth (at the U.S.G.S. Gaging Station) is 27.3 km (17 miles). The Yellow River below Plymouth passes through primary rural areas for 64.3 km (40 miles) to the Kankakee River. Since so little is known about conditions downstream from combined sewer discharges during storm conditions, these long relatively uninterrupted downstream reaches assure that D.O. measurements can be extended downstream as far as necessary.

Several other sites studied also possess certain advantages; however, overall, Bremen and Plymouth appear to be the best choice. These other sites include Chesterton, Ligonier and Nappanee. Additional D.O. measurements below North Liberty may also be useful, especially if model verification is desired when unusual features are present.

No distinct oxygen sag was found which was attributed to combined sewer discharges in any of the studies reported herein. A more intense monitoring effort may have uncovered these sags, however, none of the data suggests they occurred. It appeared, based on this limited study, that the oxygen demand resulting from combined sewer discharges, and other sources, was satisfied at a rate greater than demand by the receiving stream which were flowing at

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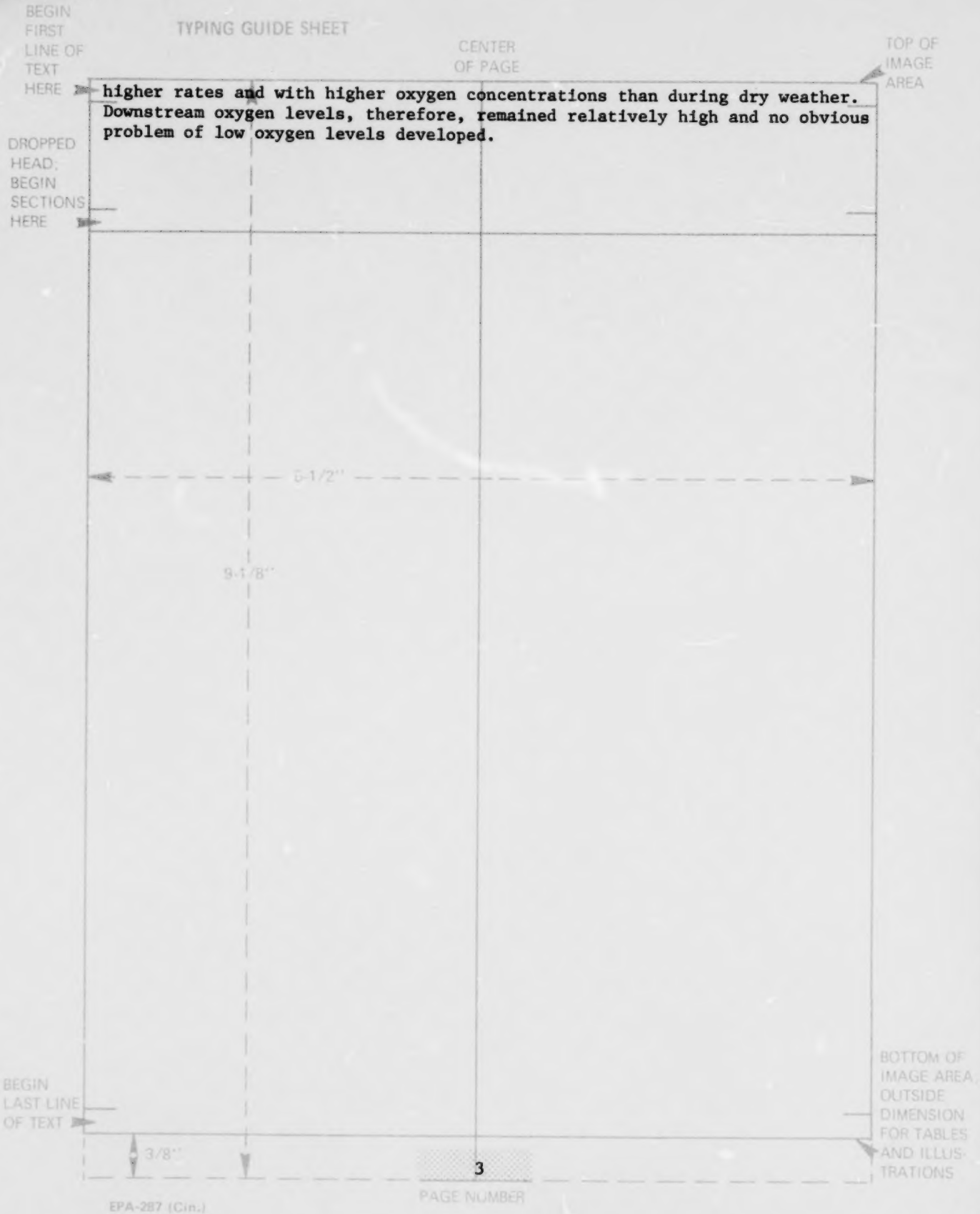
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higher rates and with higher oxygen concentrations than during dry weather. Downstream oxygen levels, therefore, remained relatively high and no obvious problem of low oxygen levels developed.
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SECTION 3

METHOD OF STUDY

SITE SELECTION

A preliminary study was conducted to identify communities in Indiana which had combined sewer discharges, urban runoff volumes which were an appreciable portion of the average stream flow and were sufficiently close to Notre Dame to facilitate collection of field data. A list of twenty-five sites, described in Table 1, was prepared. In general, sites closest to Notre Dame were investigated first. Dissolved oxygen determinations were made only at sites which appeared suited for in-depth investigations. Sites with dams, lakes or ponds, and similar features which would make monitoring for the downstream effects of combined sewer discharges difficult were eliminated from further consideration.

Since this study was of a screening nature and intended primarily to select a suitable site for future in-depth studies, it was only considered necessary to sample each downstream reach at bridges or other convenient sampling points. This constraint allowed for bracketing the potential D.O. sag, but prevented finding exactly the location of the minimum D.O. which might occur downstream during a storm event. It appeared that the only suitable method of determining this exact location was to use a boat and quickly move up and down the stream during the highly transient periods of rainfall. Since it appeared any resulting sag would likely move due to rapidly changing flows, it was decided that sampling from bridges was the only approach possible if several sites were to be examined in the one-summer period of the study.

No literature data was found to suggest methods to use to locate oxygen sags during storm events and combined sewer discharges. Based on informal discussions with personnel of the Indiana State Board of Health involved in stream measurements and stream modeling, it appeared that most D.O. sags in the streams associated with the study sites occur less than one or two miles downstream from municipal treatment plant effluents during dry weather conditions. During one attempt to locate a dry-weather sag in Wildcat Creek at Kokomo, a rainstorm occurred resulting in combined sewer discharge. The Indiana State Board of Health personnel making these measurements observed that the sag appeared to move from about one mile below the municipal wastewater treatment plant to between two and five miles downstream. It was finally assumed that for purposes of these studies, sampling would be limited to about five miles downstream for smaller streams and up to about ten miles for larger streams and would be conducted using only convenient access points, such as highway bridges.

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TABLE 1: SUMMARY OF POTENTIAL SITES SURVEY

Site Under Consideration	1 Anderson	2 Angola	3 Bluffton	4 Bremen	5 Chesterton
1970 U.S. Census Population	70,787	5,177	8,297	3,487	6,177
U.S.G.S. Gaging Station No. and Name	03348000 White River at Anderson	04099510 Pigeon Creek at Angola	Wabash River (No Station)	05516000 Yellow River at Bremen (Partial Rec. Sta.)	04094000 Little Calumet River at Porter (Down Stream Sta.)[3]
[1]Record Average Discharge, Ft^{3}/s	374	74.8	-	-	71.8
[2]1977 Monthly Ave. Discharge, Ft^{3}/s					
May	171	93.2	-	-	37.8
June	98.7	31.7	-	-	35.6
July	86.1	32.1	-	-	39.8
August	M.R.	32.7	-	-	27.9

(continued)

Notes: 1. Source: Water Resources Data for Indiana Water Year 1976. U.S.G.S. Water Data Report IN-76-1.
M^{3}/s 0.02832 x ft^{3}/s.

2. Source: Provisional - Unpublished Records Subject to Revision. Personal Correspondence U.S.G.S. Richard E. Hoggatt. (M.R. indicates missing records)

3. Down Stream Station Drainage Area, 66.2 mi^{2}.

TABLE 1 - (continued)

Site Under Consideration	1 Anderson	2 Angola	3 Bluffton	4 Bremen	5 Chesterton
[4]Drainage Area, mi^2	406	106	531	135	64
Significant Findings of Initial Contact		I/I Study			
Sites Visited		X	X	X	X
DO Measurements Reported Herein			X	X	X

(continued)

4. Source: At Gaging Station, Note 1 Source where available, otherwise Drainage Areas of Indiana Streams, by Richard E. Hoggatt, 1975 at approximately Upstream City Limits. Hectares = 259 mi^2.

TABLE 1 - (continued)

Site Under Consideration	6 Decatur	7 Goshen	8 Kokomo	9 Knox	10 LaPorte
1970 U.S. Census Population	8,445	17,171	44,042	3,519	22,140
U.S.G.S. Gaging Station No. and Name	04181500 St. Mary's River at Decatur	04100500 Elkhart River at Goshen	03333700 Wildcat Creek at Kokomo	05517000 Yellow River at Knox	Travis Ditch (No Station)
Record Average Discharge, Ft^{3}/s	496	503	225	387	-
1977 Monthly Ave. Discharge, $Ft.^{3}/s$					
May	246	399	180	M.R.	-
June	41.8	204	37.3	198	-
July	51.8	387	31.3	295	-
August	55.9	222	139	122	
Drainage Area, mi^2	621	594	242	435	Near headwater
Significant Findings of Initial Contact	I/I Study in Progress	I/I Study in Progress	I/I Study in Progress	No Combined Sewers	
Sites Visited	X	X	X		X
DO Measurements Reported Herein	X				

(continued)

TABLE 1 - (continued)

Site Under Consideration	11 Ligonier	12 Marion	13 Michigan City	14 Nappanee	15 New Castle
1970 U.S. Census Population	3,034	39,607	39,369	4,159	21,215
U.S.G.S. Gaging Station No. and Name	04100222 North Branch Elkhart River at Cosperville [5] (Upstream Sta.)	03326500 Mississinew River at Marion	04095300 Trail Creek at Michigan City	Berlin Court Ditch (No Station)	03361000 Big Blue River at Carthage [6] (Downstream Sta.)
Record Average Discharge, Ft^3/s	132	631	70.0	-	196
1977 Monthly Ave. Discharge, Ft^3/s					
May	103	382	46.5	-	95.6
June	38.6	82.9	38.9	-	50.4
July	77.2	54.9	33.5	-	32.4
August	44.9	236	M.R.	-	59.8
Drainage Area, mi^2	288	682	54.1	Near headwater	45
Significant Findings of Initial Contact		I/I Study	I/I Study	I/I Study	
Sites Visited		X	X	X	
DO Measurements Reported Herein		X		x	

(continued)

Notes: 5. Upstream Station drainage area, 142 mi^2.
6. Downstream Station drainage area, 184 mi^2.

TABLE 1 - (continued)

Site Under Consideration	16 North Liberty	17 Plymouth	18 Portland	19 Rensselear	20 Richmond
1970 U.S. Census Population	1,259	7,661	7,115	4,688	43,999
U.S.G.S. Gaging Station No. and Name	05515218 Potato Creek (Partial Recording)	05516500 Yellow River at Plymouth	03324200 Salamonie River at Portland	05522500 Iroquois River Rensselear	03275500 East Fork Whitewater River at Richmond
Record Average Discharge, Ft^3/s	-	251	72.2	164	117
1977 Monthly Ave. Discharge, Ft^3/s					
May	-	138	24.5	163	43.1
June	-	108	8.3	55.1	M.R.
July	-	195	4.1	31.0	M.R.
August	-	[c]3.7	7.65	39.1	23.0
Drainage Area, mi^2	about 27	294	85.6	203	121
Significant Findings of Initial Contact			I/I Study in Progress		I/I Study
Sites Visited	X	X	X		
DO Measurements Reported Herein		X	X		

(continued)

TABLE 1 - (continued)

Site Under Consideration	21 Syracuse	22 Valparaiso	23 Walkerton	24 Warsaw	25 Winchester
1970 U.S. Census Population	1,546	20,020	2,006	7,506	5,493
U.S.G.S. Gaging Station No. and Name	04100465 Turkey Creek at Syracuse	04094500 Salt Creek at McCool [7] (Downstream Station)	Pine Creek (No Station)	03331110 Walnut Creek at Warsaw	White River (No Station)
Record Average Discharge, Ft^3/s	34.3	72.4	-	16.6	-
1977 Monthly Ave. Discharge, Ft^3/s					
May	22.1	M.R.	-	6.83	-
June	5.47	M.R.	-	2.56	-
July	22.4	M.R.	-	7.46	-
August	17.0	M.R.	-	18.6	-
Drainage Area, mi^2	43.8	15	about 35	19.6	35
Significant Findings of Initial Contact	No Combined Sewers	I/I Study in Progress		I/I Study in Progress	
Sites Visited		X	X	X	X
DO Measurements Reported Herein					

Notes: 7. Downsteam Station drainage area, 74.6 mi^2.

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MONITORING PROCEDURES

Due to the expected peak manpower needs during storm events, the project director sought assistance from many different graduate and undergraduate student assistants working on other projects during the proposed period of investigation. One graduate student was assigned to the project full-time (20 hr/wk) during the preliminary stages of the project (April and May). This graduate student was assigned the responsibility of making initial contacts with the local personnel at the twenty-five potential survey sites gathering maps and other information needed for the study, and developing sampling procedures and conducting the initial developmental monitoring runs.

During the intensive monitoring phase of the study, June 1 through August 31, 1977, the following student assistants were utilized:

Monitoring Assistants	Percentage of Time Devoted To This Project*	Availability**
Graduate Students		
1	13%	some conflict
2	40%	essentially no conflict
Undergraduate Students		
1	100%	no conflict
2	100%	no conflict
3	62%	essentially no conflict

*Based on a full-time effort of 40 hr/wk.
**Availability indicated is for the 8 a.m. to 5 p.m. weekday periods. During evenings and weekends some conflicts did occur, however, some of these assistants were generally available and did respond to rain storm events.

In addition, on several occasions, other graduate students assisted by traveling on a monitoring run with one of the regular monitors to allow an additional two-member team to work during a storm event.

Travel was normally accomplished using the truck owned by the Department of Civil Engineering. However, whenever the truck was not available or when more than one crew was out, personal vehicles were also used.

The drought conditions occurring during the spring and summer of 1977 seriously limited the number of rainfall events that could be monitored. No totally satisfactory method was developed to accurately predict the time and

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location of storms in order to allow a field crew to always be at the site as the storm approached. In discussing methods of predicting storm events with the National Weather Service personnel for South Bend, Indiana at the Michiana Regional Airport, it appeared the most effective method was to monitor the telephone recorded weather forecasts they provided and updated on a regular basis, and to carefully watch the local television weather programs. When either of these indicated a high likelihood of a suitable storm, we were able to make telephone contact with one of the weather personnel on duty and obtain the latest information concerning the storm and their opinion on the expected intensity and location of the storm. This method worked reasonably well for the sites located near South Bend.

Similar telephone contacts were made with National Weather Service personnel for Fort Wayne, Indiana at the Baer Field Airport. Storms at sites located northwest of Notre Dame, the direction from which many storms move toward Notre Dame, were the most difficult to anticipate. In this case, after making many trips to gather data during anticipated storms which failed to materialize, a local treatment plant operator agreed to call us when it appeared a storm was eminent. Unfortunately, no such storm developed prior to conclusion of the study. All crews were stationed at Notre Dame, except one field crew which worked out of Fort Wayne for a short period of time.

MONITORING METHODS

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D.O. concentrations and temperatures were determined with a Yellow Springs Instrument Model 54-ARC D.O. meter. Generally, a 30 m (100 ft) cable was used and measurements taken from highway overpasses by lowering the probe approximately 0.3 m (1 ft) below the water surface. Wading was also used at some stations were bridges were not available and streams were shallow.

The descriptions of each sample location, reported in a subsequent section are generally based on observations during dry weather conditions. Depths of these streams did not change significantly except during the storm designated as Storm IV which occurred on June 3, 1977 and was a relatively large storm. In this case, the streams were all observed to be approximately one to two meters higher. Most combined sewer discharges occurred below the stream water surfaces, therefore, most were not readily visible. Based on those which could be seen discharging, including obvious discharges from known combined sewer overflow locations, and discussions with local personnel, it was concluded that all sites did have combined sewer overflows during storm events.

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SECTION 4

RESULTS AND DISCUSSION

SITE EVALUATION

Of the twenty-five Indiana sites identified in Table 1 as potential stream survey locations, only the cities of Knox and Syracuse were found to have separate rather than combined sewers. Site visits were made to nineteen of the twenty-five communities. Due to limitation of time and because of the greater distances from Notre Dame, four communities, Anderson, New Castle, Rensselear, and Richmond, were not visited. Table 1 provides a summary of these initial contacts and indicates where D.O. data were collected and reported herein. The next few paragraphs discuss sites which were identified as being relatively unsuitable for future in-depth studies.

D.O. measurements were taken at four locations downstream from Angola during dry weather conditions and found to range from 6.4 to 8.9 mg/ℓ. The recieving stream is rather unusual since the municipal treatment plant effluent discharges into Fish Pond which flows into Mud Lake through Wood Ditch before reaching Pigeon Creek. Due to this unusual receiving water system, Angola was excluded from further consideration.

Dry weather D.O. measurements downstream from Goshen showed a slight drop apparently due to the sewage treatment plant effluent (6.9 mg/ℓ to 6.4 mg/ℓ) with a gradual recovery to 8.1 mg/ℓ at a distance of approximately 6.5 km (4 miles) downstream. The Goshen site was also excluded from further consideration because of the limited number of convenient downstream sampling locations, but more importantly, because of the infrequency of combined sewer overflows. The treatment plant was expanded resulting in excess capacity which eliminated bypass except during major storm events. There are five combined sewer discharge points.

Kokomo appeared to have several major industrial waste discharges, which local municipal employees believed would seriously interfere with observation of the effects of combined sewer overflows. Based on this report, additional consideration of this site was not provided, although suitable results may be possible especially if the relative magnitudes of various effluent discharges are of interest.

D.O. levels downstream from the LaPorte wastewater treatment plant were found to be very low during dry weather conditions (2.6 to 4.3 mg/ℓ). Further complicating the observation of the effects of combined sewer overflows is the fact that all four overflows pass through a 6.5 ha (16 acres) lagoon

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before reaching the receiving stream. This would facilitate sampling the overflows and would allow a minimum cost for installing monitoring equipment. However, even with this significant advantage, the site was excluded due to the low stream D.O. levels during dry weather conditions and because the existing lagoon might serve as a treatment system.

The Michigan City site was eliminated from further consideration since the last combined sewer diversion is located only a little more than 3 km (2 miles) upstream from Lake Michigan. In addition, only two convenient sample locations were found in this short reach of stream.

North Liberty is a potential site. However, due to limitation of time, and the presence of reported industrial wastes, needed additional site visits were not made prior to completion of the project. The local wastewater treatment plant operator indicated the presence of a slaughterhouse in the vicinity of the combined sewer overflow points and believed these slaughterhouse waste discharges would interfere with observation of the effects of combined sewer discharges. If additional sites are needed, and industrial-type discharges are of interest, North Liberty may warrant a more detailed examination. Several dry weather measurements indicated relatively high D.O. levels in Potato Creek.

Valparaiso offers some advantages as a survey site. These are: 1) all three combined sewer diversion points are located at the treatment plant site, 2) the receiving stream is relatively small, and 3) the only other significant wastewater discharge is from the municipal treatment plant. Because of the lack of convenient sampling locations, however, the site was not given additional consideration. The stream flows between two railroad tracks for a relatively long distance with no bridges for several miles downstream. The use of a boat would probably be the only suitable method of measuring downstream conditions.

Walkerton currently is in need of a wastewater treatment plant. Therefore, due to the difficulty of determining the relative impact of the insufficiently treated wastewater and the combined sewer diversions, this site was not given further consideration.

Warsaw has areas served by both combined and separate sewers. The relative impact of the municipal wastewater treatment plant effluent, the separate storm sewer discharges and the combined sewer diversions would be difficult to determine. In addition, some of these discharges pass through a lake prior to entering the receiving stream. Warsaw was therefore also excluded from further consideration.

The nine remaining sites were investigated in more detail and constitute a list from which several suitable in-depth survey sites may be selected. The locations of these sites relative to one another are shown on Figure 1. These sites are discussed in the following sections.

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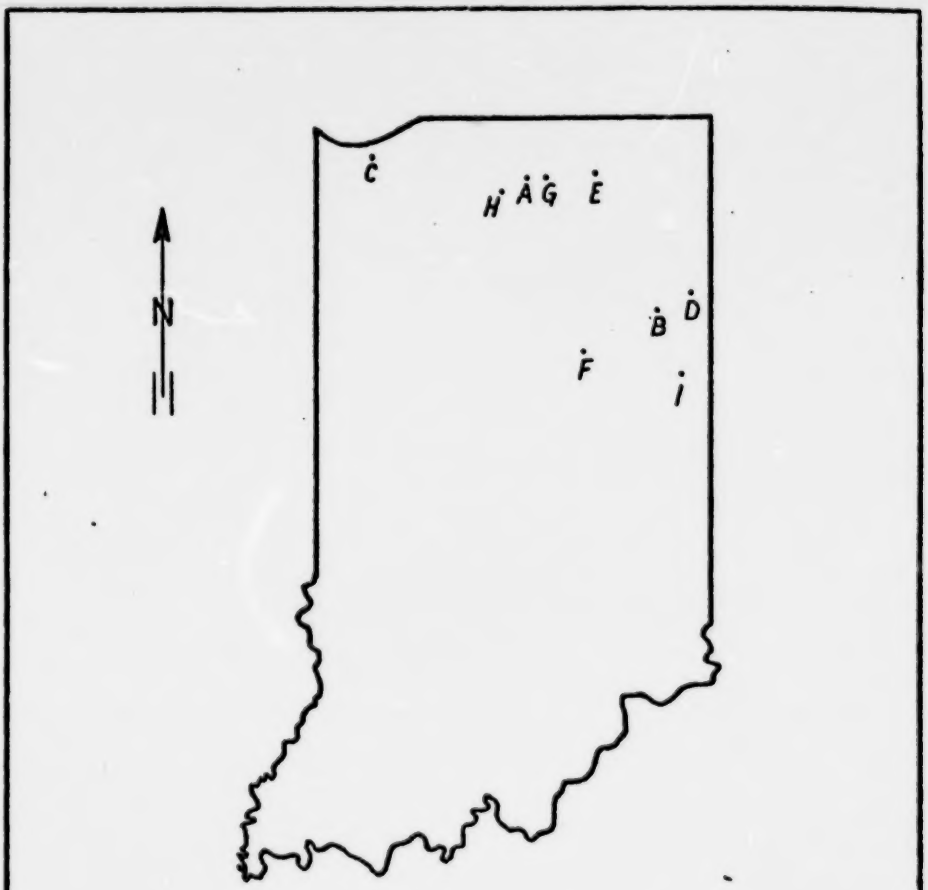

FIGURE 1

RELATIVE LOCATIONS OF SAMPLE SITES IN INDIANA

Designation	Site
A	Bremen
B	Bluffton
C	Chesterton
D	Decatur
E	Ligonier
F	Marion
G	Nappanee
H	Plymouth
I	Portland

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STREAM SURVEYS AND RAINFALL RECORDS

The nine sites surveyed are listed in Table 2. This listing includes names of the receiving streams, names of the U.S.G.S. Quadrangle maps showing these communities, and the times and weather conditions during each field measurement period. Of the fifty-seven different field measurement surveys completed at these nine stations, almost half were completed during or after a rain storm.

Due to a below average number of rainfall events during May through August, 1977, the period in which the study was conducted, not as much wet weather D.O. data was collected as originally planned for. Not only was rainfall rare, but several events occurred during early morning hours or on Sundays when field crews were generally not available. There were, however, eight significant storms during or shortly after which field measurements were taken. These storms had total rainfalls of between 1.1 and 6.5 cm (0.45 to 2.54 in.) which provided a good range of rainfall intensities.

Table 3 provides a summary of the hourly rainfalls for each of these storms and indicates the sites and time during which river surveys were completed. The rainfall summary data has been taken from the National Weather Service records for the stations at South Bend and Fort Wayne, Indiana.

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Site A - Bremen

Bremen, Indiana is located approximately 40 km (25 miles) south of Notre Dame. Its effluents are discharged into the Armey Ditch and the Yellow River near the headwaters of the Yellow River. Bremen is a small town with a 1970 population of 3,487 and a land area within the corporate limits of 34 ha (1.3 sq. miles).

The capacity of the municipal wastewater treatment plant is 0.04 m^3/s (0.9 mgd). Average dry weather flows are about ten percent less than this with peaks reaching 0.06 m^3/s (1.4 mgd). Wet weather conditions, therefore, result in frequent waste diversion. These diversions occur at six points along Armey Ditch and two directly into Yellow River, one at the treatment plant and the other downstream from the location of the municipal treatment plant.

These streams are both relatively small and easily accessible for sampling and monitoring. Stream widths vary from 7.5 to 15 m (25 to 50 ft) with depth up to approximately 0.75 m (2.5 ft) during dry weather conditions and only a meter or so higher during storms. The channel bottom tends to be relatively soft and mucky. Near the combined sewer diversion points, mucky bottom deposits of 0.3 to 0.5 m (1 to 1.5 ft) are present over a sand and gravel bottom. Eight combined sewer overflows exist and all discharge above normal water levels making sampling and monitoring convenient. The area

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TABLE 2: INDIANA STREAM SURVEY PERIODS

Site Designation	Community	Stream	USGS Quadrangle Maps	Weather Condition	Measurement Periods	
					Dates	Time
A	Bremen	Arney Ditch & Yellow River	Bremen	after rainfall	5/06/77	4:00 pm - 6:20 pm
				dry weather	5/14/77	11:45 am - 3:05 pm
				dry weather	5/21/77	11:45 am - 2:30 pm
				dry weather	5/31/77	2:30 pm - 3:20 pm
				after rainfall	6/05/77	12:42 pm - 1.20 pm
				dry weather	6/13/77	3:10 pm - 4:50 pm
				dry weather	6/22/77	7:20 am - 9:30 am
				after rainfall	6/29/77	9:05 am - 11:11 am
				during rainfall	6/30/77	12:35 pm - 1:45 pm
				after rainfall	6/30/77	7:20 pm - 8:35 pm
				after rainfall	7/01/77	11:50 am - 12:50 pm
				dry weather	7/08/77	11:50 am - 1:00 pm
				after rainfall	7/12/77	11:05 am - 1:10 pm
B	Bluffton	Wabash River	Bluffton	dry weather	8/16/77	11:55 am - 12:40 pm
				after rainfall	8/16/77	2:30 pm - 3:10 pm
C	Chesterton	Coffee Creek & Little Calumet River	Chesterton	dry weather	6/06/77	10:00 am - 1:00 pm
				dry weather	6/13/77	10:30 am - 12:00 pm
				dry weather	6/21/77	10:30 am - 12:05 pm
				dry weather	6/28/77	10:25 am - 12:20 pm
				dry weather	7/07/77	9:55 am - 11:25 am
D	Decatur	St. Mary's River	Decatur & Hougland	dry weather	8/11/77	10:00 am - 11:40 am
				after rainfall	8/11/77	7:45 pm - 8:50 pm
				dry weather	8/16/77	9:20 am - 10:35 am
E	Ligonier	Elkhart River	Ligonier	dry weather	5/27/77	12:00 pm - 3:00 pm
				dry weather	6/02/77	1:50 pm - 4:00 pm
				after rainfall	6/05/77	4:55 pm - 5:35 pm
				dry weather	6/14/77	2:30 pm - 3:30 pm
				dry weather	6/22/77	1:55 pm - 2:50 pm
				after rainfall	6/29/77	2:40 pm - 4:00 pm
				during rainfall	6/30/77	5:00 pm - 5:55 pm
				after rainfall	7/01/77	8:35 am - 9:20 am
				dry weather	7/08/77	8:00 am - 9:00 am
				after rainfall	8/08/77	11:30 am - 1:30 pm
F	Marion	Mississinewa River	Marion	dry weather	8/15/77	1:45 pm - 3:50 pm
G	Nappanee	Berlin Court Ditch	Nappanee	dry weather	5/24/77	1:00 pm - 3:00 pm
				dry weather	5/31/77	4:25 pm - 5:20 pm

(continued)

TABLE 2 (continued)

Site Designation	Community	Stream	USGS Quadrangle Maps	Weather Condition	Measurement Periods	
					Dates	Time
G	Nappanee	Berlin Court Ditch	Nappanee	after rainfall	6/05/77	3:15 pm - 4:15 pm
				dry weather	6/14/77	12:40 pm - 1:50 pm
				dry weather	6/22/77	11:50 am - 1:20 pm
				after weather	6/29/77	12:15 pm - 2:10 pm
				during rainfall	6/30/77	2:20 pm - 3:25 pm
				after rainfall	6/30/77	7:05 pm - 8:25 pm
				after rainfall	7/01/77	10:00 am - 11:00 am
				dry weather	7/08/77	9:45 am - 11:00 am
H	Plymouth	Baker Ditch & Yellow River	Plymouth	dry weather	5/25/77	10:15 am - 12:35 pm
				dry weather	5/31/77	11:00 am - 1:00 pm
				after rainfall	6/05/77	10:35 am - 11:40 am
				dry weather	6/14/77	9:40 am - 11:30 am
				dry weather	6/21/77	2:00 pm - 4:10 pm
				dry weather	6/28/77	2:15 pm - 3:45 pm
				after rainfall	6/29/77	5:45 pm - 7:00 pm
				during rainfall	6/30/77	10:10 am - 11:30 am
				during rainfall	6/30/77	5:20 pm - 6:22 pm
				after rainfall	7/01/77	1:20 pm - 3:00 pm
				dry weather	7/07/77	1:40 pm - 3:45 pm
I	Portland	Salamonie River	Portland	dry weather	8/11/77	1:15 pm - 2:20 pm
				during rainfall	8/11/77	5:05 pm - 6:40 pm

TABLE 3: RAINFALL AND SAMPLE RUN RECORD

Storm Designation	Rainfall Data*			Site	Sample Date	Sample Times
	Date of Storm	Hour Ending at	Hourly Rainfall in Inches			
I	(5/04/77)	12 pm	0.29	A-Bremen	5/06/77	4:00 pm - 6:20 pm
	5/05/77	1 am	0.08			
		2 am	0.02			
		3 am	0			
		4 am	T			
		5 am	0.06			
		Total	0.45			
II	6/05/77	6 am	T	A-Bremen	6/05/77	12:42 pm - 1:20 pm
		7 am	0.27	E-Ligonier	6/05/77	4:55 pm - 5:35 pm
		8 am	0.17	G-Nappanee	6/05/77	3:15 pm - 4:15 pm
		9 am	0.06	H-Plymouth	6/05/77	10:35 am - 11:40 am
		10 am	T			
		Total	0.50			
III	6/28/77	11 am	T	A-Bremen	6/29/77	9:05 am - 11:11 am
		12 am	0.05	E-Ligonier	6/29/77	2:40 pm - 4:00 pm
		1 pm	0	G-Nappanee	6/29/77	12:15 pm - 2:10 pm
		2 pm	0	H-Plymouth	6/29/77	5:45 pm - 7:00 pm
		3 pm	0.20			
		4 pm	0.32			
		5 pm	0			
		6 pm	0			
		7 pm	0			
		8 pm	T			
		9 pm	0.57			
		10 pm	0.01			
		Total	1.15			
IV	6/30/77	9 am	0.20	A-Bremen	6/30/77	12:35 pm - 1:45 pm
		10 am	0.29		6/30/77	7:20 pm - 8:35 pm
		11 am	0.21		7/01/77	11:50 am - 12:50 pm
		12 am	0.75	E-Ligonier	6/30/77	5:00 pm - 5:55 pm
		1 pm	0.08		7/01/77	8:35 am - 9:20 am
		2 pm	T	G-Nappanee	6/30/77	2:20 pm - 3:25 pm
		3 pm	T		6/30/77	7:05 pm - 8:25 pm
		4 pm	0.96		7/01/77	10:00 am - 11:00 am
		5 pm	0.04	H-Plymouth	6/30/77	10:10 am - 11:30 am
		6 pm	T		6/30/77	5:20 pm - 6:22 pm
		7 pm	0.01		7/01/77	1:20 pm - 3:00 pm
		Total	2.54			

(continued)

TABLE 3 (continued)

Storm Designation	Rainfall Data*			Site	Sample Date	Sample Times
	Date of Storm	Hour Ending at	Hourly Rainfall in Inches			
V	7/12/77	8 am	T	A-Bremen	7/12/77	11:05 am - 1:10 pm
		9 am	T			
		10 am	0.66			
		11 am	0.03			
		12 am	0			
		1 pm	0			
		2 pm	0.41			
		3 pm	T			
		Total	1.10			
VI	8/08/77	6 am	0.92	E-Ligonier	8/08/77	11:30 am - 1:30 pm
		7 am	0.17			
		8 am	0.19			
		9 am	0.11			
		10 am	0.02			
		11 am	T			
		Total	1.41			
VII	8/11/77	4 pm	1.28	D-Decatur	8/11/77	7:45 pm - 8:50 pm
		5 pm	0.07			
		6 pm	0.03			
		7 pm	0.03			
		8 pm	0.03	I-Portland	8/11/77	5:05 pm - 6:40 pm
		9 pm	0.02			
		10 pm	T			
		Total	1.46			
VIII	8/16/77	1 pm	0.33	B-Bluffton	8/16/77	2:30 pm - 3:10 pm
		2 pm	0			
		3 pm	0			
		4 pm	0			
		5 pm	0			
		6 pm	0			
		7 pm	0			
		8 pm	0.12			
		Total	0.45			

*Rainfall Data based on U.S. Weather Service data reported in Monthly Summary, Local Climatological Data, for South South Bend, Indiana (expect Storms VII and VIII for which Fort Wayne, Indiana was used).

surrounding Bremen is primarily agricultural with significant livestock pasture areas. Several small ditches enter Armey Ditch and the Yellow River in the area investigated, but none appeared to have significant flow.

A U.S.G.S. Gaging Station is located near the sampling location identified as Station 11 in Figure 2, however, it is not an active station and no flows are recorded. A stage-discharge relationship is available and could be used for stream flows at this location.

The first sampling station is about one mile upstream from the first combined sewer overflow. The location of each station and a brief physical description is given in Figure 2 and Table 4. D.O. measurements and temperatures under various weather conditions are reported in Table 5.

Site B - Bluffton

Bluffton, Indiana is approximately 40 km (25 miles) south of Fort Wayne, Indiana and about 180 km (110 miles) from Notre Dame. The Wabash River flows through Bluffton, a 1040 ha (4.0 sq. miles) community with a 1970 population of 8,297.

Sampling is not convenient. Only two of the four sampling stations located in this five-mile reach were from bridges. The other two, and any additional sites needed are river bank locations. The four sampling stations are shown in Figure 3 and described in Table 6. Although no U.S.G.S. Gaging Station is available; a local, nonrecording station is available.

The wet weather D.O. determinations were essentially the same as those found during dry weather conditions. This may be accounted for by the observation reported by the field crew that no combined sewer diversions appeared even though more than one cm (0.45 in.) of rainfall had occurred. The results of these measurements are reported in Table 7.

Site C - Chesterton

Chesterton, Indiana is located almost 80 km (50 miles) west of Notre Dame. Combined sewer diversions are made to Coffee Creek and the Little Calumet River. Coffee Creek joins the Little Calumet River within the town limits. The 1970 population was 6,177 with 1090 ha (4.2 sq. miles) within the town limits.

Chesterton appeared to be a well suited site for in-depth studies based on its location relative to Notre Dame, its limited number of combined sewer overflows, three, the size of the community and the streams, and the presence of a U.S.G.S. Gaging Station. However, no wet weather data were obtained. This was because being located west of Notre Dame, storms which generally moved from west to east, were through the area before reaching Notre Dame. Field crews could therefore not reach the site during these storms. The numerous dry weather runs were a result of weather predictions which indicated a rainstorm was likely to occur but which never materialized.

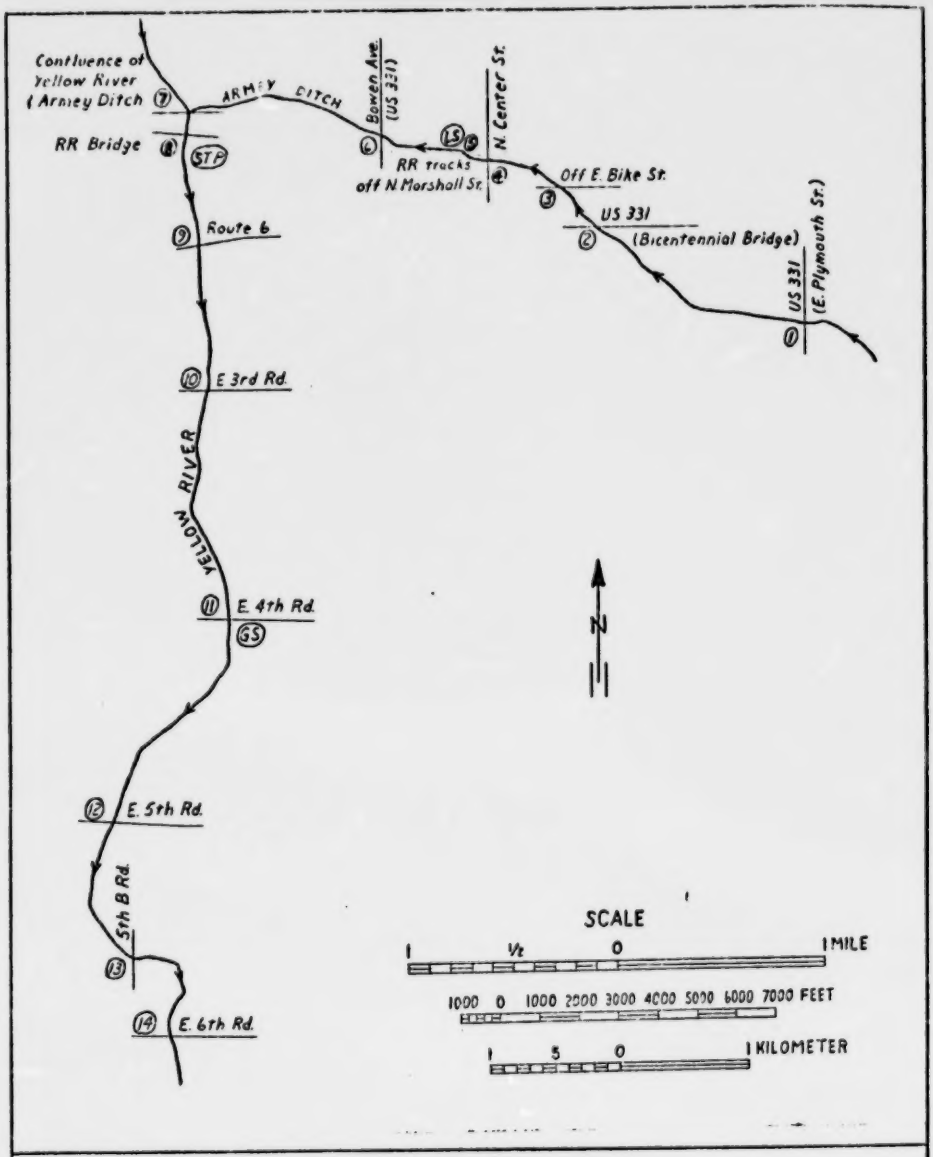

FIGURE 2

SITE A-BREMEN STATION LOCATIONS

Legend

(1) Sampling Station Location
(STP) Sewage Treatment Plant
(GS) Stream Gaging Station
(LS) Lift Station

TABLE 4: SAMPLING STATION DESCRIPTION

Site A-Bremen

Station Number	Location	Cummulative Distance From Station 1		Remarks
		Miles	Kilometers	
1	U.S. 331 (E. Plymouth St.) & Armey Ditch	0	0	Armey Ditch is approximately 20' wide x 4' deep with an approximate velocity of 0.5 - 1.0 fps. The water here is muddy and turbid, while the bottom sediments are very mucky.
2	U.S. 331 (Bicentennial Bridge) & Armey Ditch	1.16	1.87	At this station, Armey Ditch is approximately 30' wide x 4' deep, with an approximate velocity of 0.5 fps. The water here is turbid and muddy, with tree limbs and other debris present. The river bottom is mucky, approximately 1-2 ft. deep. A combined sewer overflow (CSO) is visible here.
3	Off E. Bike Street & Armey Ditch	1.42	2.29	At this station, the river is approximately 21' wide by 1' deep, with a velocity of 0.5 fps. The water is turbid and muddy, with riffles. This station requires sampling from an overhanging tree.
4	N. Center Street & Armey Ditch	1.85	2.98	At this station, the river is approximately 18' wide by 2.5' deep, with a velocity of 1.0 fps. The banks are steep, and there are logs, branches, and debris blocking the river about 100 ft. upstream, near a CSO.

(continued)

TABLE 4 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks
		Miles	Kilometers	
5	N. Marshall St at Pumping Station & Armey Ditch	2.03	3.27	At this station, the river is 16' wide by 1.5' deep, with a velocity of 1.0 fps. The river runs through a cement channel where the sample was taken which is underneath RR tracks. There is some riffle area downstream, and a pair of storm sewers are visible near the lift station.
6	N. Bowen Ave. & Armey Ditch	2.40	3.86	At this station, the river is 17' wide and 1' deep, with a velocity of 1.5 fps. The water is turbid and muddy, while the channel bottom is more sand than muck.
7	Confluence of Yellow River & Armey Ditch	3.41	5.49	At this station, Yellow River is 3' wide and 2" deep before the confluence, while it is 18' wide by 4" deep, with a velocity of 1.5 fps after the confluence. The water is clearer at this station while the channel bottom is sand and clay, with some gravel. D.O. measurements taken by wading.

(continued)

TABLE 4 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks
		Miles	Kilometers	
8	RR Crossing & Yellow River	3.56	5.73	At this station, the river is 20' wide by 1.5' deep with a velocity of 1.0 - 1.5 fps. The water becomes muddy and turbid once again with the channel bottom changing to muck. This station is close to the WWTP effluent, and can only be reached on foot.
9	Rt. 6 & Yellow River	4.05	6.52	**At this station, the river is approximately 50' wide by 3' deep.
10	E. 3rd Rd. & Yellow River	4.76	7.66	At this station, the river is approximately 60' wide and 4' deep.
11	E. 4th Rd. & Yellow River	5.47	8.80	At this station, the river is approximately 50' wide by 4' deep. There is also a USGS Gaging Station near the southeast edge of the sampling bridge.
12	E. 5th Rd. & Yellow River	7.00	11.27	The river is approximately 60' wide and 2' deep with a sand bar at midstream.

(continued)

TABLE 4 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks
		Miles	Kilometers	
13	5th B Rd. & Yellow River	7.27	11.70	The river is approximately 40' wide and 4-5' deep at this point.
14	E. 6th Rd. & Yellow River	7.75	12.47	The river is approximately 60' wide and 2-3' deep at this point.

*All D.O. sampling taken from bridges unless otherwise note. Right and left defined facing downstream.
**All stations after and including station #9 are similar in physical appearance. The water is muddy and turbid, while the bottom is mainly muck. These stations are all in rural areas.

Eight combined sewer overflows exist. Six are approximately uniformly spaced between Stations 1 and 6, one at the sewage treatment plant and the last about half-way between Stations 8 and 9.

TABLE 5: DISSOLVED OXYGEN DETERMINATIONS FOR SITE A-BREMEN

Sample Station	Dissolved Oxygen in mg/ℓ and Temperature in °C for Various Weather Conditions							
	STORM I 5/06/77 After Rainfall 4:00 pm to 6:20 pm		5/14/77 Dry Weather 11:45 pm to 3:05 pm		5/21/77 Dry Weather 11:45 am to 2:30 pm		5/31/77 Dry Weather 2:30 pm to 3:20 pm	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	-	-	9.6	17.0	-	-	8.9	22.6
2	3.0	15.5	8.7	NA	5.7	19.5	10.0	22.2
3	4.6	15.5	10.2	17.5	5.6	19.8	-	-
4	4.1	15.8	8.7	17.5	6.5	20.2	8.1	21.2
5	3.9	15.8	8.3	17.5	6.6	21.0	-	-
6	6.6	16.0	8.2	18.0	6.8	20.2	8.5	21.6
7	-	-	7.7	19.0	-	-	-	-
8	6.6	16.0	8.0	20.0	7.1	22.5	-	-
9	3.6	16.0	8.1	20.0	6.8	22.5	7.6	23.0
10	-	-	-	-	-	-	-	-
11	6.4	16.2	7.7	19.2	6.9	21.5	7.0	21.8
12	-	-	-	-	-	-	-	-
13	-	-	-	-	-	-	6.2	20.8
14	-	-	-	-	7.3	21.0	6.2	21.0

(continued)

TABLE 5 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	STORM II 6/5/77 After Rainfall 12:42 pm - 1:20 pm		6/13/77 Dry Weather 3:10 pm - 4:50 pm		6/22/77 Dry Weather 7:20 am - 9:30 am		STORM III 6/29/77 After Rainfall 9:05 am - 11:11 am	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	7.6	19.8	8.4	18.0	5.9	15.6	5.8	18.7
2	6.0	21.0	9.9	18.0	5.5	16.9	5.6	19.1
3	-	-	-	-	-	-	-	-
4	5.8	20.2	8.0	17.2	6.4	16.9	5.7	18.8
5	5.9	20.0	-	-	-	-	-	-
6	4.5	20.0	7.2	17.0	4.4	16.7	5.4	18.8
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	4.1	20.0	8.5	17.8	6.5	17.1	6.2	18.3
10	5.1	19.8	7.3	17.8	6.3	16.8	5.8	18.2
11	6.5	19.5	8.4	17.5	6.7	17.0	5.5	18.2
12	-	-	7.0	17.0	6.2	17.3	-	-
13	5.8	19.5	6.6	16.5	7.1	17.3	5.6	18.8
14	-	-	6.9	16.0	6.0	17.2	5.6	19.0

(continued)

TABLE 5 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	STORM IV 6/30/77 During Rainfall 12/35 pm to 1:45 pm		STORM IV 6/30/77 After Rainfall 7:20 pm to 8:35 pm		STORM IV 7/1/77 After Rainfall 11:50 am to 1:00 pm		7/8/77 Dry Weather 11:50 am to 12:50 pm	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	7.4	17.8	6.7	18.3	5.8	18.6	6.8	20.8
2	7.3	17.8	6.7	18.0	5.9	18.5	5.8	21.0
3	-	-	-	-	-	-	-	-
4	7.0	17.9	6.8	18.0	6.2	18.8	6.0	20.0
5	-	-	-	-	-	-	-	-
6	6.4	18.0	6.7	18.2	6.2	18.9	5.8	20.1
7	-	-	-	-	-	-	-	-
8	-	-	-	-	-	-	-	-
9	-	-	6.5	18.0	6.2	18.5	6.3	21.8
10	6.2	18.1	6.4	18.1	6.1	18.3	5.9	21.5
11	6.9	18.0	6.5	18.2	6.2	18.7	6.1	21.4
12	-	-	-	-	-	-	5.9	21.3
13	7.2	18.0	6.5	18.3	6.1	18.6	6.2	21.5
14	7.0	18.0	6.6	18.1	6.2	18.1	5.9	21.5

(continued)

TABLE 5 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	STORM V 7/12/77 After Rainfall 11:05 am to 1:10 pm	
	DO(mg/ℓ)	Temp(^{o}C)
1	4.8	18.8
2	4.9	18.9
3	-	-
4	5.8	19.0
5	-	-
6	5.0	21.0
7	-	-
8	5.2	20.8
9	5.5	21.0
10	5.4	20.3
11	6.1	20.0
12	-	-
13	6.3	20.0
14	-	-

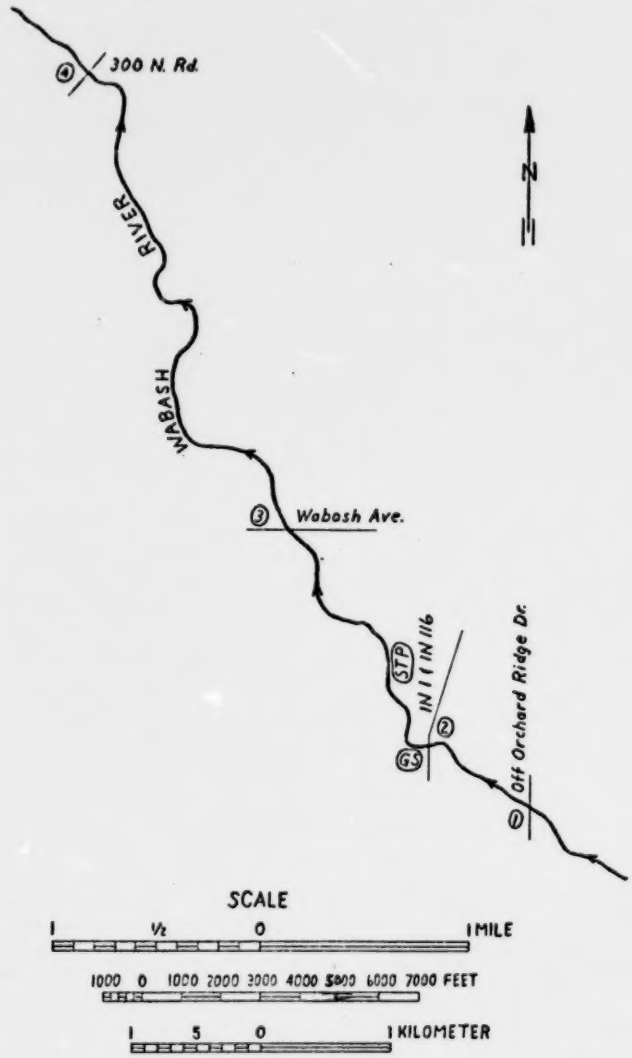

FIGURE 3

SITE B-BLUFFTON STATION LOCATION

Legend

(1) Sampling Station Location
(STP) Sewage Treatment Plant
(GS) Stream Gaging Station

TABLE 6: SAMPLING STATION DESCRIPTION

SITE B-BLUFFTON

Number	Location	Cummulative Distance From Station 1		Remarks
		Miles	Kilometers	
1	Off Orchard Ridge Dr. & Wabash River	0	0	At this station, the river is approximately 40' wide and 3' deep, with sluggish velocity. The water is muddy with a rocky bottom, while the banks are grassy with some trees visible.
2	IN 1 & IN 116 & Wabash River	0.66	1.07	At this station, the river is approximately 100' wide with a depth of 3 ft. and a velocity of 1.5 fps. The water is muddy, and some grasses grow in the water and on the banks.
3	Wabash Ave. & Wabash River	2.08	3.35	At this station, the river is approximately 50' wide and 2' deep, with a velocity of 1.5 fps. The water is silty, with many grassy areas in the stream and on the banks.
4	300 N. & Wabash River	5.02	8.08	At this station, the river is approximately 70 ft. wide and 3 ft. deep, with sluggish velocity. The water is muddy with much vegetation, while the banks are tree- and brush-lined.

The location and number of combined sewer discharge points was not determined due to the difficulty of sampling and unlikelihood of selecting this site for an indepth study.

TABLE 7: DISSOLVED OXYGEN DETERMINATIONS FOR SITE B-BLUFFTON

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C
For Various Weather Conditions

Sample Station	8/16/77 Dry Weather 11:55 am to 12:40 pm		8/16/77 After Rainfall 2:30 pm to 3:10 pm	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	7.0	25.0	7.1	25.0
2	7.2	25.0	7.3	25.0
3	7.3	25.0	7.3	25.0
4	8.4	25.0	8.8	24.5

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Sampling stations are shown in Figure 4 and described in Table 8 with D.O. determination shown in Table 9. The primary treatment facilities at the municipal treatment plant have a rated capacity of 0.1 m^3/s (2.2 mgd), and the secondary facilities have a rated capacity of only 0.07 m^3/s (1.5 mgd). Therefore, in addition to direct combined sewer overflows significant amounts of primary effluent reach the streams.

Site D - Decatur

Decatur, Indiana is located 32 km (20 miles) southeast of Fort Wayne and more than 160 km (100 miles) from Notre Dame. St. Mary's River flows through Decatur with a U.S.G.S. Gaging Station in the vicinity of Decatur. Although a relatively small community, 8,445 population in 1970 with a land area of 725 ha (2.8 sq. miles), it has thirteen combined sewer diversion points. All diversions are into St. Mary's River upstream from the municipal treatment plant.

Table 10 provides a description of each of the seven sampling stations and Figure 5 shows their locations. D.O. concentrations are quite low during dry weather conditions and appear to be somewhat higher during storm conditions. Due to these low dry weather D.O. concentrations, shown in Table 11, it appears Decatur is not well suited for additional study.

9-1/8"

Site E - Ligonier

Ligonier, Indiana, located approximately 65 km (40 miles) southeast of Notre Dame, had a 1970 population of 3,034 and a land area of 470 ha (1.8 sq. miles). The Elkhart River passes through the town with seven combined sewer discharge points located upstream from the municipal treatment plant.

Sampling locations are relatively convenient and seven were used over the 12 km (7.5 miles) reach studied. These are shown in Figure 6 and described in Table 12 which also shows the stream to be relatively small and suitable for additional in-depth study. Ligonier, like Bremen, received considerable attention due to its apparent suitability for in-depth studies. The results of the D.O. determinations are shown in Table 13, and indicate relatively widely ranging concentrations even during dry weather conditions.

Site F - Marion

Marion, Indiana, the largest community considered in these more detailed studies, had a 1970 population of 39,607 and a land area of 2500 ha (9.6 sq. miles). Marion is one of the more distant communities studied being located about 160 km (100 miles) from Notre Dame.

Its effluents are discharged into the Mississinewa River a little more than 16 km (10 miles) upstream from the Mississinewa Reservoir. Table 14 describes the sampling stations and indicates the characteristics of the river in the vicinity of each station. These seven stations, shown in

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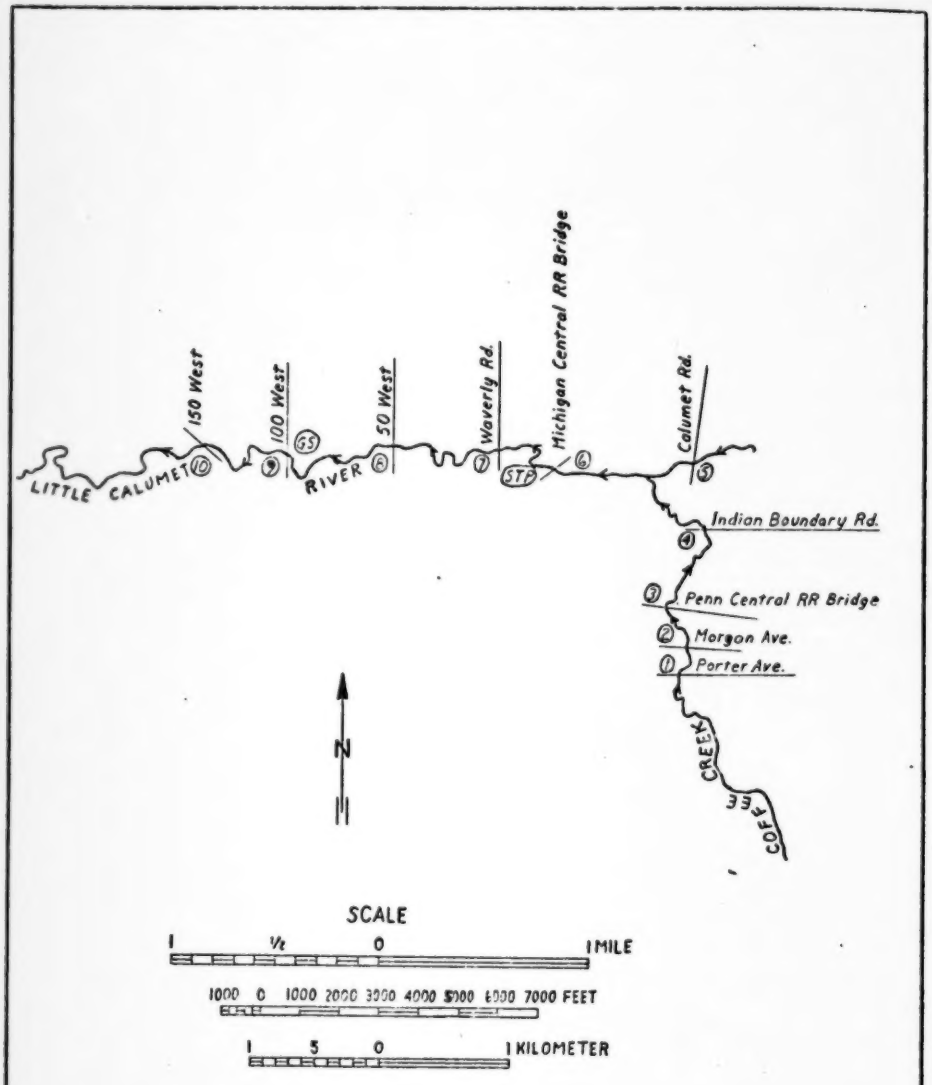

FIGURE 4

SITE C-CHESTERTON STATION LOCATIONS

Legend

(1) Sampling Station
(STP) Sewage Treatment Plant
(GS) Stream Gaging Station

TABLE 8: SAMPLING STATION DESCRIPTION

SITE C-CHESTERTON

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Porter Ave. & Coffee Creek	0	0	Width: 36 ft., Depth: 1 ft., Velocity: 3 fps. The area is full of driftwood, tree limbs, etc. which partially block the creek upstream. An overflow is visible along the left downstream side, and is partially submerged.
2	Morgan St. & Coffee Creek	0.15	0.24	Width: 30 ft., Depth: 2 ft., Velocity: 1 fps. The water is littered with driftwood, cans and tree limbs. One 2' drain is visible, just downstream and to the left of the bridge.
3	Penn Central RR Bridge & Coffee Creek	0.38	0.61	Width: 42 ft., Depth: 1 ft., Velocity: 2.5 fps. The water is cluttered with driftwood and junk, which creates a rapids-type effect just downstream of the bridge.
4	Indiana Boundary Rd. & Coffee Creek	0.84	1.35	Width: 24 ft., Depth: 2 ft., Velocity: 1 fps. Two corrugated drain pipes are visible at this station: An 8" pipe just downstream and an 18" pipe approximately 20 ft. up stream.

(continued)

TABLE 8 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
5	Calumet River & Little Calumet River	0.38 (before confluence of Coffee Creek & L.C.R.	0.61	Width: 50 ft., Depth: 4 ft., Velocity: 1 fps
6	Michigan Central RR Bridge & Little Calumet River	1.66	2.67	Width: 45 ft., Depth: 2 ft., Velocity: 1 fps. This is the first station downstream of the confluence of Coffee Creek with the Little Calumet River. A sandbar is visible at about midstream, just downstream of the bridge. The WWTP effluent can be seen entering the river, just upstream of this station.
7	Waverly Rd. & Little Calumet River	2.02	3.25	Width: 50 ft., Depth: 2 ft., Velocity: 1 fps. Some tree limbs and sticks strewn about in the water. A small drainage ditch enters from the highway, on the downstream side to the right.
8	50 West & Little Calumet River	2.63	4.23	Width: 55 ft., Depth: 3 ft., Velocity: 1 fps. Riprap lines the side by the bridge and two drainage ditches enter here from the road.

(continued)

TABLE 8 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
9	100 West & Little Calumet River	3.36	5.41	Width: 50 ft., Depth: 3 ft., Velocity: 1 fps. There is a USGS Gaging Station located on the right downstream side of the bridge.
10	150 West & Little Calumet River	4.12	6.63	Width: 54 ft., Depth: 5 ft., Velocity: 0.5 fps.

*The water at Coffee Creek stations is clear with rocky bottoms, while the water at Little Calumet River stations is a mucky, chocolate brown. All D.O. measurements were taken from bridges unless otherwise noted, and all width, depth and velocity measurements are approximate. Right and left defined facing downstream.

There are three combined sewer overflows. One is located just downstream from Station 1 in Coffee Creek, another is just downstream from Station 5 in the Little Calument River and the last is at the Sewage Treatment Plant.

TABLE 9: DISSOLVED OXYGEN DETERMINATIONS FOR SITE C-CHESTERTON

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Condition

Sample Station	6/6/77 Dry Weather 10:00 am to 1:00 pm		6/13/77 Dry Weather 10:30 am to 12:00 pm		6/21/77 Dry Weather 10:30 am to 12:05 pm		6/28/77 Dry Weather 10:25 am to 12:20 pm	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	8.4	18.0	8.9	16.0	9.6	18.5	9.7	22.5
2	8.3	17.5	9.1	15.9	9.6	18.2	7.8	21.7
3	8.6	17.3	9.3	15.7	10.2	19.2	8.5	22.4
4	8.1	17.5	8.9	15.7	9.2	18.5	7.4	21.9
5	6.9	17.5	8.2	15.2	7.7	18.8	6.0	21.7
6	7.0	17.4	8.5	15.0	8.4	18.7	7.1	21.0
7	7.0	17.4	8.2	15.8	7.9	18.8	7.0	21.0
8	7.3	17.4	8.1	15.0	7.6	18.9	6.6	21.6
9	6.5	17.4	8.2	15.5	7.6	19.8	6.1	21.2
10	-	-	-	-	-	-	-	-

(continued)

TABLE 9 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	7/7/77 Dry Weather 9:55 am to 11:25 am	
	DO(mg/ℓ)	Temp(^{o}C)
1	7.3	24.8
2	-	-
3	7.0	25.1
4	6.3	25.0
5	6.0	24.0
6	6.4	24.7
7	6.4	24.5
8	6.1	24.9
9	6.0	24.9
10	5.2	24.4

TABLE 10: SAMPLING STATION DESCRIPTION

SITE D-DECATUR

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Erie RR Crossing & St. Mary's River	0	0	Width: 30 ft., Depth: 3 ft., Velocity: 1.5 fps. Banks are lined with trees and brush.
2	US 224 & US 33 & St. Mary's River	0.57	0.91	Width: 60 ft., Depth: 4 ft., Velocity: 0.5 fps. Banks are grassy. An 18" conduit is visible on the left, downstream side.
3	Monmouth Rd. & St. Mary's River	1.66	2.67	Width: 50 ft., Depth: 2 ft., Velocity: 1.0 fps. Banks are lined with trees and brush.
4	US 27 & US 33 & St. Mary's River	2.23	3.58	Banks are lined with trees and brush. A USGS Gaging Station is located on the downstream, right. Central Soya's effluent (industry) from their lagoons flows at approximately 100 gpm, about 100 ft. downstream, on the right.
5	S 613 & St. Mary's River	5.82	9.37	Width: 50 ft., Depth: 4 ft., Velocity: 1 fps. Banks are lined with trees and brush.

(continued)

TABLE 10 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
6	S 592 & St. Mary's River	8.84	14.22	Width: 90 ft., Depth: 3 ft., Velocity: 2 fps. Bridge divides stream into two 45 ft. channels. The right channel was used in sampling.
7	1200 N & St. Mary's River	11.63	18.71	Width: 50 ft., Depth: 2.5 ft., Velocity: 2 fps. Stream is split by an island into a 50 ft. channel and 20 ft. channel. The 50 ft. channel was used for sampling.

*For each station, the water observed to be very muddy, with foam and small sticks floating on the surface. All D.O. measurements were taken from bridges, and all width, depth, and velocity measurements are approximate. Right and left defined facing downstream.

The thirteen combined sewer overflows are approximately uniformly spaced between Stations 1 and the Sewage Treatment Plant.

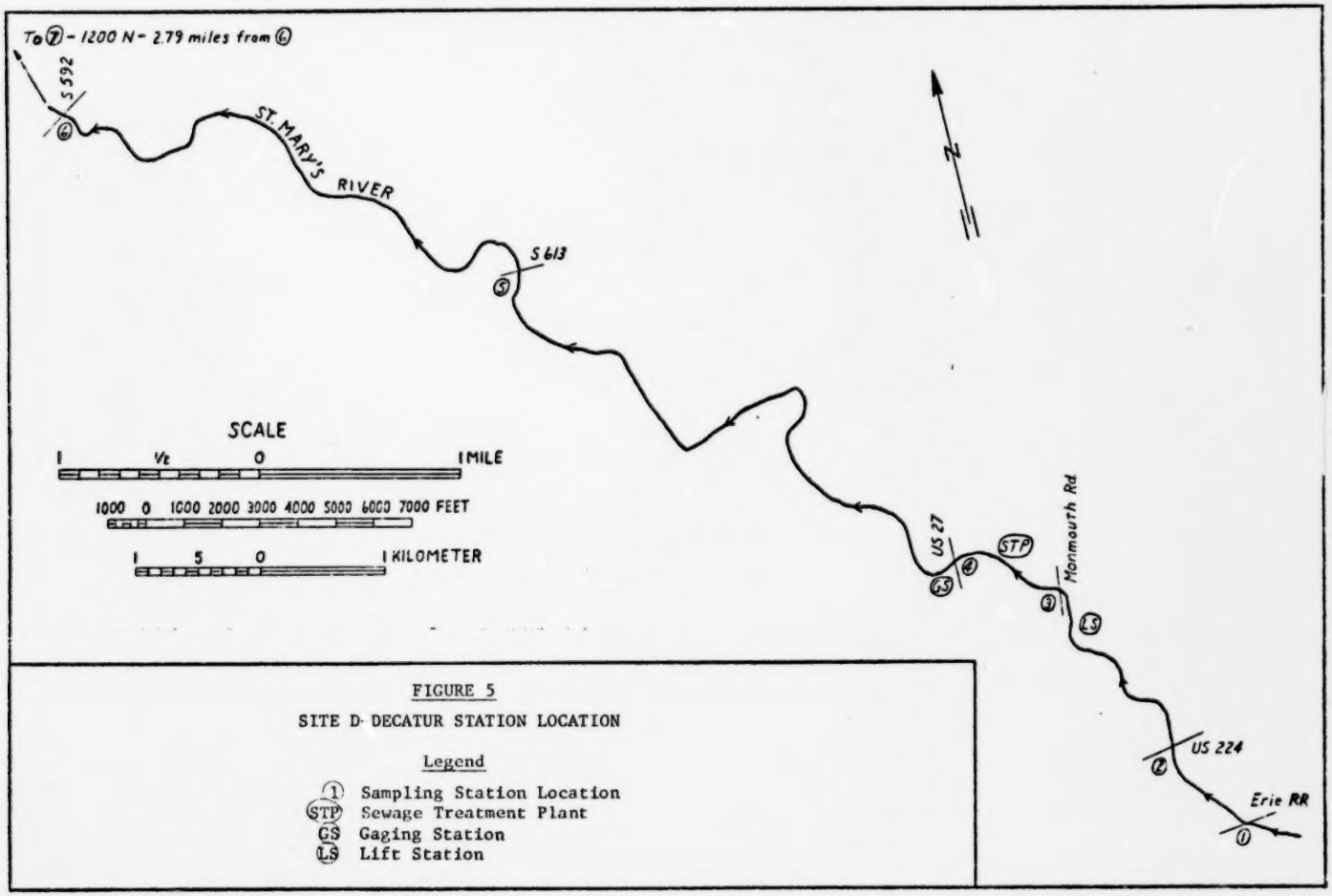

FIGURE 5

SITE D- DECATUR STATION LOCATION

Legend

(1) Sampling Station Location
(STP) Sewage Treatment Plant
(GS) Gaging Station
(LS) Lift Station

TABLE 11: DISSOLVED OXYGEN DETERMINATIONS FOR SITE D-DECATUR

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	8/11/77 Dry Weather 10:00 am to 11:40 am		STORM VII 8/11/77 After Rainfall 7:45 pm to 8:50 pm		8/16/77 Dry Weather 9:20 am to 10:35 am	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	5.2	22.0	5.2	23.0	5.8	23.0
2	4.8	22.5	7.0	23.0	5.6	23.0
3	4.8	22.5	7.2	23.0	5.5	23.0
4	4.6	23.0	7.1	23.0	5.3	23.0
5	3.4	22.5	6.3	23.0	4.2	23.5
6	3.0	23.0	6.3	25.0	4.5	23.0
7	4.7	23.5	4.1	24.0	4.5	23.0

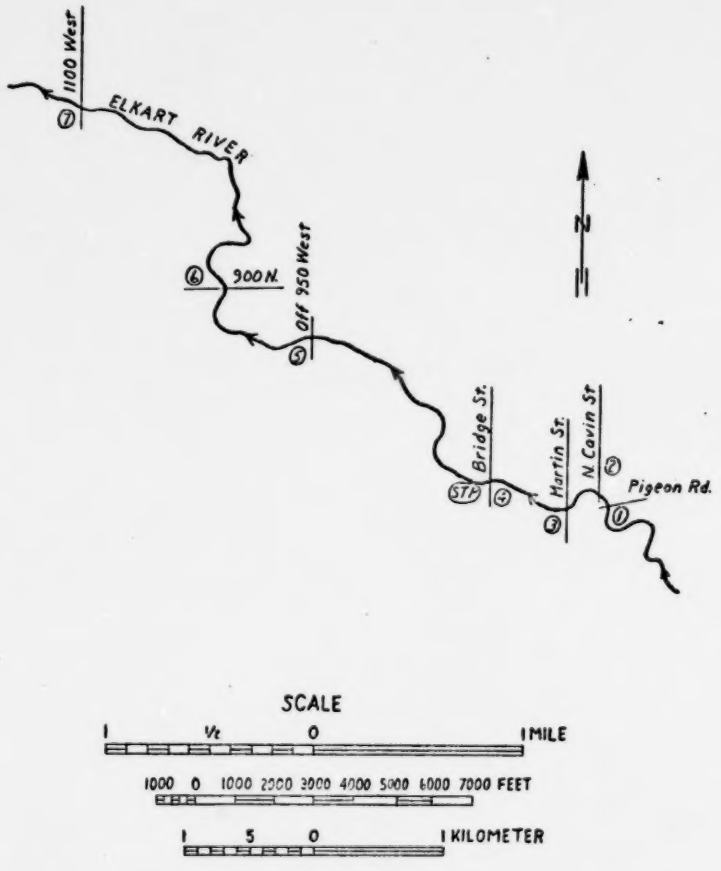

FIGURE 6

SITE E-LIGONIER STATION LOCATION

Legend

1 Sampling Station Location
STP Sewage Treatment Plant

TABLE 12: SAMPLING STATION DESCRIPTION

SITE E-LIGONIER

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Pigeon Rd. & Elkhart River	0	0	Width: 75 ft., Depth: 1 ft., Velocity: 1 fps. Many weeds growing upstream. A submerged pipe is slightly visible on the right downstream side, while a second, slightly submersed pipe is visible on the left, upstream side.
2	N. Cavin St. & Elkhart River	0.05	0.08	Width: 90 ft., Depth: 2 ft., Velocity: 1 fps. An outfall is visible on the right downstream side, with a flow of approximately 100-150 gpm. A submerged pipe can be seen on the left, upstream side.
3	Martin St. & Elkhart River	0.27	0.43	Width: 75 ft., Depth: 1 ft., Velocity: 2 fps. A rocky, uneven bottom causes rippling here. Outfalls are visible in several places: 1) on the right downstream side, with a flow of 30-50 gpm; 2) on the left, downstream side, with a flow of 2 gpm; 3) on the left upstream side, with a flow of 40-50 gpm; 4) 2 other pipes are submerged, on the right and left downstream side.

(continued)

TABLE 12 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
4	Bridge St. & Elkhart River	0.66	1.06	Width: 75 ft., Depth: 1.5 ft., Velocity: 1 fps. This station is just upstream of the WWTP effluent outflow. Some weeds located along the bottom.
5	Off 950 West & Elkhart River	1.70	2.74	Width: 75 ft., Depth: 1.5-2.0 ft., Velocity: 1 fps. Downstream of the WWTP. Stream is filled with bottom vegetation.
6	900 N & Elkhart River	2.56	4.12	Width: 90 ft., Depth: 4 ft., Velocity: 0.5 fps. Stream is filled with weeds and bottom vegetation.
7	1100 W & Elkhart River	4.64	7.47	Width: 90 ft., Depth: 3 ft., Velocity: 1 fps. Some vegetation located upstream. Also some rippling occurring due to higher velocity.

*The water at all stations is clear or slightly mucky, with bottom vegetation visible. All D.O. measurements were taken from bridges, and all width, depth, velocity, and outflow measurements are approximate. Right and left are defined facing downstream.

The seven combined sewer overflows are approximately uniformly spaced between Station 1 and the Sewage Treatment Plant.

TABLE 13: DISSOLVED OXYGEN DETERMINATIONS FOR SITE E-LIGONIER

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	5/27/77 Dry Weather 12:00 pm to 3:00 pm		6/2/77 Dry Weather 1:50 pm to 4:00 pm		STORM II 6/5/77 After Rainfall 4:55 pm to 5:35 pm		6/14/77 Dry Weather 2:30 pm to 3:30 pm	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	7.8	24.3	7.6	20.0	8.8	23.8	9.3	20.5
2	7.8	24.3	7.6	20.0	-	-	9.5	20.3
3	4.6	23.8	8.0	19.0	8.4	23.8	9.6	20.3
4	7.0	23.8	8.8	20.0	7.6	23.5	9.5	20.3
5	-	-	7.9	19.3	7.8	23.2	9.9	21.0
6	10.0	24.5	10.6	20.0	9.1	23.5	10.0	20.3
7	10.8	24.8	5.1	19.8	8.2	23.5	11.2	20.0

(continued)

TABLE 13 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	6/22/77 Dry Weather 1:55 pm to 2:50 pm		STORM III 6/29/77 After Rainfall 2:40 pm to 4:00 pm		STORM IV 6/30/77 During Rainfall 5:00 pm to 5:55 pm		STORM IV 7/1/77 After Rainfall 8:35 am to 9:20 am	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	10.0	22.0	8.2	24.0	7.1	20.2	6.2	18.4
2	9.0	21.8	8.1	24.0	6.7	20.1	6.1	18.3
3	9.4	21.7	8.0	24.0	6.7	20.1	6.1	18.3
4	9.3	21.9	7.7	23.8	6.8	20.3	6.1	18.6
5	8.4	22.4	7.8	23.9	-	-	6.1	18.9
6	11.6	22.6	8.7	24.5	6.2	20.0	6.0	18.6
7	12.2	22.0	9.5	24.5	6.3	19.5	6.2	18.4

(continued)

TABLE 13 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	7/8/77 Dry Weather 8:00 am to 9:00 am		STORM VI 8/8/77 After Rainfall 11:30 am to 1:30 pm	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	4.4	25.0	6.4	23.0
2	3.5	25.0	-	-
3	4.2	25.0	6.3	23.0
4	4.4	25.0	6.2	23.0
5	4.6	24.9	6.3	23.0
6	4.7	24.9	5.9	23.0
7	5.0	24.9	7.7	23.0

TABLE 14: SAMPLING STATION DESCRIPTION

SITE F-MARION

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Pennsylvania Ave. & Mississinewa River	0	0	Width: 60 ft., Velocity: 2 fps. Grasses growing along channel bottom.
2	IN 18 & Mississinewa River	1.70	2.74	Width: 120 ft., Depth: 4 ft., Velocity: 0.5 fps. Little or no vegetation in the stream.
3	Washington St. & Mississinewa River	2.56	4.11	Width: 200 ft.; Velocity: sluggish. Two cubicles are located on the south downstream side, with manholes on top and a submerged 18" gate. An 18" conduit is located on the north, downstream side.
4	Highland Ave. & Mississinewa River	3.69	5.94	Width: 120 ft., Depth: 3 ft., Velocity: 2.5 fps. Much vegetation in the stream. A dam, with one gate and a fish ladder is located 300 ft. upstream. A USGS Gaging Station is located on the left downstream side, and a rapids can be seen farther downstream.

(continued)

TABLE 14 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
5	IN 37 & IN 9 & Mississinewa River	4.26	6.86	Width: 120 ft., Velocity: 2.0 fps. A rapids can be seen approximately 300 ft. downstream. Much vegetation lines the stream bed.
6	IN 15 & Mississinewa River	7.77	12.50	Width: 200 ft.: Velocity: 2.5 fps. An island downstream diverts most of the flow to the left.
7	500 N. & Mississinewa River	10.13	16.31	Width: 150 ft., Velocity: 2 fps. Water is clogged with vegetation upstream.

*At all stations, the water is very muddy and the banks are lined with trees and bushes. All D.O. measurements were taken from bridges and all width, depth, and velocity measurements we approximate. Right and left are defined facing downstream.

The number of combined sewer overflows is uncertain but they are apparently located between Station 1 and the Sewage Treatment Plant.

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Figure 7, span most of the reach from Marion to the upper end of the Mississinewa Reservoir. A U.S.G.S. Gaging Station is present near Station 4.

Due to the unusually high dry weather D.O. concentrations, the presence of a dam near Station 4 and the lack of rainfalls during the last few days available for stream sampling, no wet weather measurements were made. The dry weather data are shown in Table 15.

Site G - Nappanee

Nappanee, Indiana is located only about 40 km (25 miles) south and a little east of Notre Dame. The 1970 population was 4,159 with a land area of 410 (1.6 sq. miles). The Berlin Court Ditch, a small stream, passes through Nappanee and collects effluents from the municipal treatment plant and twelve combined sewer overflows.

The stream can be easily waded for sampling and all combined sewer overflows are above normal water levels making sampling these discharges convenient. The stream tends to have a soft mucky bottom and exhibits exceptionally low D.O. levels. These low levels were observed upstream from combined sewer and the municipal discharge points even during dry weather conditions. Tables 16 and 17 include the sample site descriptions and D.O. data, respectfully. Figure 8 provides locations of each station.

9-1/8"

Although Nappanee exhibits many characteristics which would make it suitable for further in-depth studies, it appears the low upstream D.O. levels (and probable organic loadings) would make modeling difficult due to the high upstream organic loading. Also, no gaging station is presently available.

Site H - Plymouth

Plymouth, Indiana, located on the Yellow River about 25 km (15 miles) downstream from Bremen and about 40 km (25 miles) south of Notre Dame, had a population of 7,661 with a land area of 1040 ha (4.0 sq. miles).

Eleven combined sewer overflows discharge into the Yellow River which winds through the center of Plymouth. Sampling stations are described in Table 18 and shown on Figure 9. A U.S.G.S. Gaging Station is located within the corporation limits.

Oxygen sags appear to be common during dry weather flows as shown in Table 19. The municipal treatment plant discharges between Stations 5 and 6, and most observed sags occurred downstream from this point. Station 1, generally exhibiting a high D.O. level, is in Baker Ditch just upstream from the confluence of the Yellow River. This probably indicates a relatively high quality water addition to the Yellow River and would not seriously interfere with modeling of this stream. Wet weather D.O. levels, as presented in Table 19, show a pattern similar to that observed during dry weather periods.

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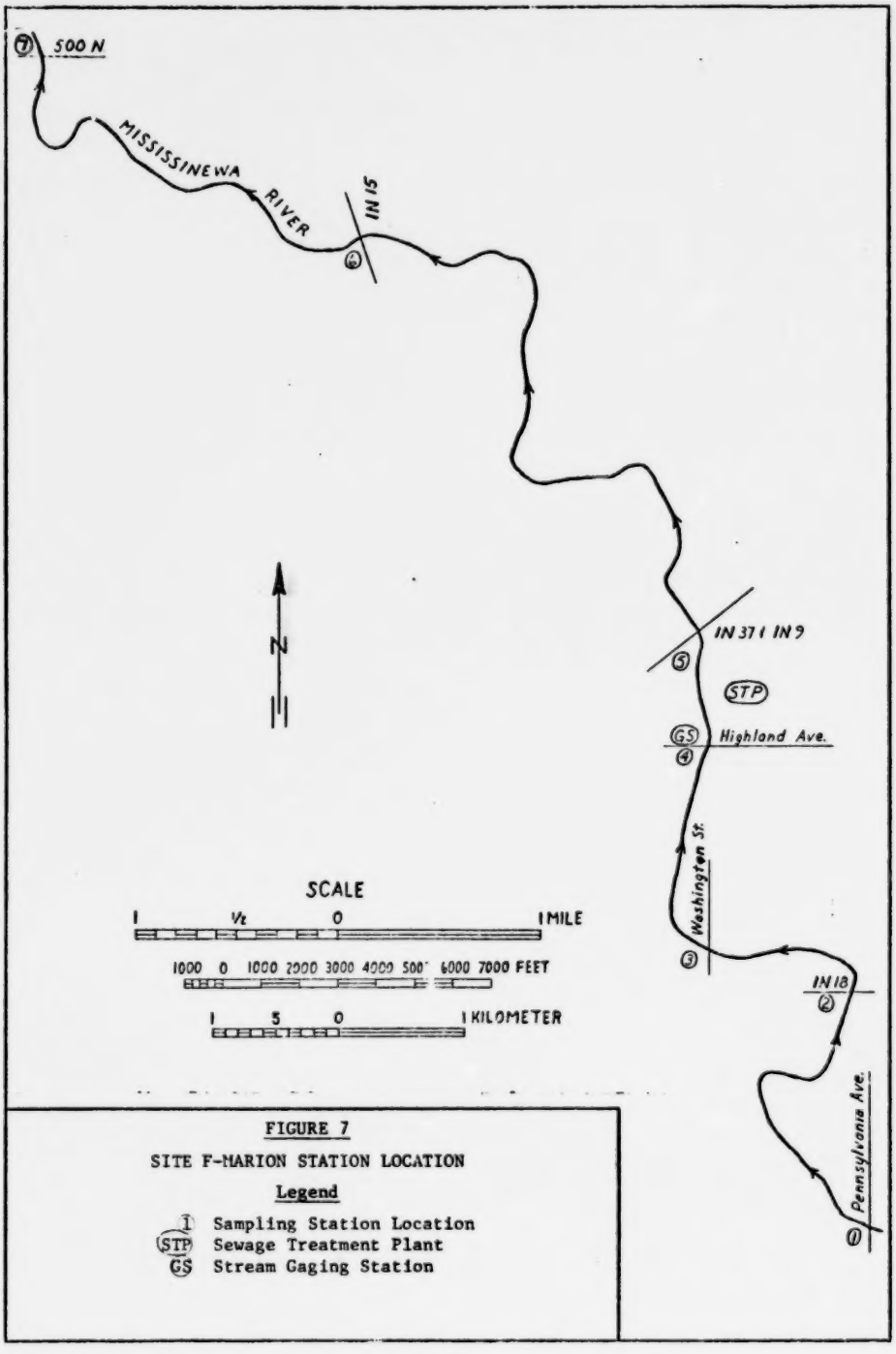

FIGURE 7

SITE F-MARION STATION LOCATION

Legend

1 Sampling Station Location
STP Sewage Treatment Plant
GS Stream Gaging Station

TABLE 15: DISSOLVED OXYGEN DETERMINATIONS FOR SITE F-MARION

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	8/15/77 Dry Weather 1:45 pm to 3:50 pm	
	DO(mg/ℓ)	Temp(°C)
1	9.1	24.0
2	9.2	24.0
3	9.3	23.0
4	10.2	23.5
5	10.4	24.0
6	12.6	25.0
7	11.4	24.5

TABLE 16: SAMPLING STATION DESCRIPTION

SITE G-NAPPANEE

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Main St. (IN 19) Berline Ct. Ditch	0	0	Width: 14-16 ft., Depth: 6-10" Velocity: <.5 fps. D.O. measured by wading. Rocks under bridge provide slight aeration. Some algae present.
2	Elm St. & Berlin Ct. Ditch	0.09	0.14	Width: 16 ft., Depth: 1 ft., Velocity: <0.5 fps. D.O. measured by wading. Stream has very muddy bottoms and algal blooms. A noticeable odor of sewage is present.
3	Madison St. & Berlin Ct. Ditch	0.19	0.31	Width: 16 ft., Depth: 1 ft., Velocity: <0.5 fps. D.O. measured by wading. Sewage odor is present.
4	Jackson St. & Berlin Ct. Ditch	0.49	0.79	Width: 18 ft., Depth: 6-10", Velocity: <0.5 fps. D.O. measured off foot bridge. 48" sewer outlet located under bridge. Stream bottom littered with debris.
5	Marion St. & Berlin Ct. Ditch	0.89	1.43	Width: 15 ft., Depth: 6-8", Velocity: <0.5 fps. D.O. measured by wading. 48" sewer outlet on right bank, facing downstream. Field drainage on opposite bank. Rocks downstream create a small rapids. Sewage odor is present. Last station upstream of WWTP.

(continued)

TABLE 16 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
6	Co. Rd 7 & Berlin Ct. Ditch	1.23	1.98	Width: 16 ft., Depth: 8-12", Velocity: 0.5 fps. D.O. measured by wading. Bottom is very mucky, no algae or odor present. This is the first station downstream of WWTP.
7	US 6 & Berlin Ct. Ditch	1.99	3.20	Width: 16 ft., Depth: 1 ft., Velocity: 0.5 fps. Rocks under bridge cause a small rapids condition.
8	Co. Rd 9 & Berlin Ct. Ditch	2.60	4.18	Width: 15 ft., Depth: 10", Velocity: <0.5 fps. Small dam made of tree limbs and driftwood partially block down stream flow. Grease or scum evident on the surface near the dam.
9	Co. Rd 11 & Berlin Ct. Ditch	3.88	6.24	Width: 15 ft., Depth: 1 ft., Velocity: 0.5 fps. Bottom appears to be more rocky and sandy.
10	Co. Rd 13 & Berlin Ct. Ditch	4.92	7.92	Width: 12 ft., Depth: 6-10", Velocity: 0.5 fps. Bottom appears more rocky and sandy.

*Water at all stations upstream of WWTP is virtually stagment, with mucky bottoms, algal growths, and a strong odor of sewage. Stations downstream of WWTP have clearer water, but with mucky bottoms. All D.O. measurements are taken from bridges unless noted, and all width, depth, and velocity measurements are approximate.

The twelve combined sewer overflows are located between Stations 1 and 5.

TABLE 17: DISSOLVED OXYGEN DETERMINATIONS FOR SITE G-NAPPANEE

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	5/24/77 Dry Weather 1:00 pm to 3:00 pm		5/31/77 Dry Weather 4:25 pm to 5:20 pm		STORM II 6/5/77 After Rainfall 3:15 pm to 4:15 pm		6/14/77 Dry Weather 12:40 pm to 1:50 pm	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	5.7	24.9	4.6	23.5	1.1	23.0	1.5	18.4
2	6.7	25.8	-	-	-	-	-	-
3	6.7	25.5	-	-	-	-	-	-
4	5.1	23.5	3.0	21.5	1.4	21.2	1.5	18.8
5	3.7	21.2	4.8	20.3	1.4	20.5	1.7	17.5
6	9.0	20.0	7.7	19.0	4.7	20.0	7.3	18.0
7	6.7	21.2	4.6	21.0	3.0	20.2	4.3	18.0
8	7.5	21.2	5.0	21.0	3.0	21.0	3.8	18.0
9	-	-	5.0	21.0	4.0	21.0	5.1	18.0
10	-	-	-	-	5.5	21.5	-	-

(continued)

TABLE 17 (continued)

Sample Station	Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions							
	6/22/77 Dry Weather 11:50 am to 1:20 pm		STORM III 6/29/77 After Rainfall 12:15 pm to 2:10 pm		STORM IV 6/30/77 During Rainfall 2:20 pm to 3:25 pm		6/30/77 After Rainfall 7:05 pm to 8:25 pm	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	1.8	20.2	1.2	22.5	5.3	18.8	3.7	18.3
2	-	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-	-
4	1.8	20.5	0.8	20.3	5.9	19.0	4.3	18.5
5	1.8	19.4	0.8	19.2	7.0	18.8	-	-
6	7.6	18.8	6.0	20.4	5.8	18.9	5.3	18.4
7	4.5	17.8	3.9	20.1	6.4	18.7	6.0	18.5
8	4.4	18.1	4.4	20.2	6.6	18.8	6.5	18.8
9	5.7	18.7	4.8	21.0	7.0	18.6	7.0	19.0
10	7.5	18.9	6.5	21.1	7.1	18.7	7.1	19.0

(continued)

TABLE 17 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in ^{o}C For Various Weather Conditions

Sample Station	STORM IV 7/1/77 After Rainfall 10:00 am to 11:00 am		7/8/77 Dry Weather 9:45 am to 11:00 am	
	DO(mg/ℓ)	Temp(^{o}C)	DO(mg/ℓ)	Temp(^{o}C)
1	4.3	18.5	1.3	23.5
2	-	-	-	-
3	-	-	-	-
4	4.3	18.0	1.7	23.2
5	4.4	18.0	0.6	22.0
6	4.8	18.3	4.7	21.7
7	5.5	18.0	3.7	21.4
8	5.8	18.0	3.9	21.5
9	6.6	18.2	5.6	22.1
10	6.6	18.3	5.3	22.0

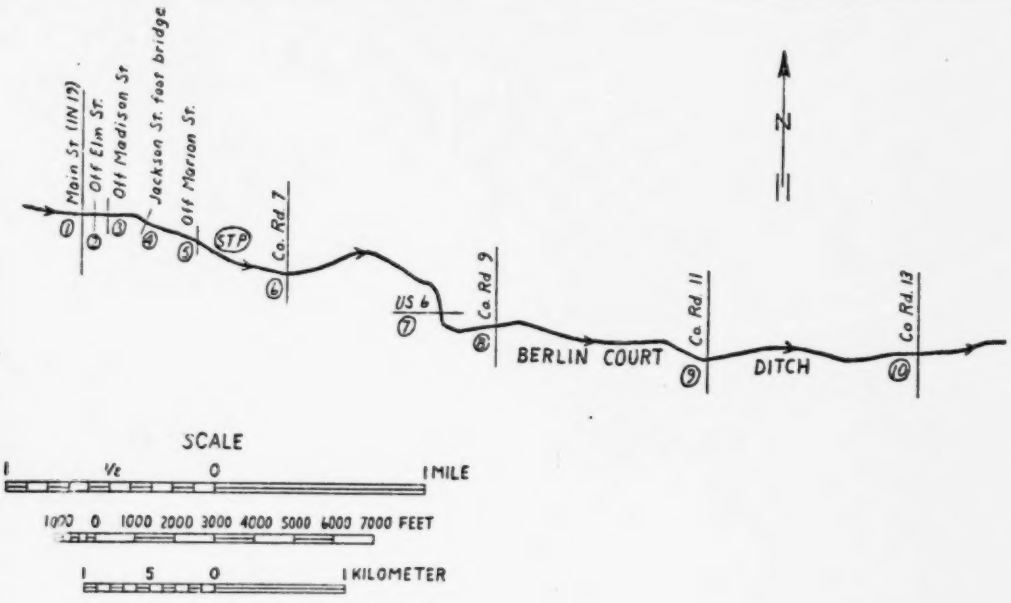

FIGURE 8

SITE G-NAPPANEE STATION LOCATION

Legend

① Sampling Station Location
STP Sewage Treatment Plant

TABLE 18: SAMPLING STATION DESCRIPTION

SITE H-PLYMOUTH

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Off Goshen Rd. & Baker Ditch	0	0	Width: 10 ft., Depth: 8-10", Velocity: 1.5 fps. D.O. measured by wading. Water is clear, with no algal growth. Rocks underneath bridge cause a rapids effect.
2	Off Goshen Rd. & Yellow River	0	0	Width: 75-80 ft., Depth: 2 ft., Velocity: 1 fps. Station is just upstream of confluence with Baker Ditch. Not much vegetation on slopes.
3	Baker St. & Yellow River	0.30	0.48	Width: 65-75 ft., Depth: 1.5-2 ft., Velocity: 1.5 fps. Banks are lined with trees and bushes.
4	Jefferson St. & Yellow River	0.89	1.43	Width: 90 ft., Depth: 2 ft., Velocity: 2 fps. Right, downstream bank is steep with trees and bushes. Left downstream bank not as steep, with less vegetation. Some turbulence caused by bridge supports.
5	Garro St. & Yellow River	1.15	1.85	Width: 120 ft., Depth: 2 ft., Velocity: 1.5 fps. A sand bar directly behind bridge support blocks flow slightly. River narrows and curves upstream. Banks are shallow, with vegetation.

(continued)

TABLE 18 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
6	Pierce St. & Yellow River	1.75	2.82	Width: 100 ft., Depth: 1.5 ft., Velocity: 1 fps. Logjam of tree limbs and driftwood partially block the river upstream. Banks have much vegetation.
7	W 11th Rd. & Yellow River	4.31	6.94	Width: 75-80 ft., Depth: 1.5 ft., Velocity: 1 fps. First station downstream of WWTP. Banks are lined with many trees and vegetation.
8	W 12th Rd. & Yellow River	5.60	9.01	Width: 75 ft., Depth: 4 ft., Velocity: 0.5 fps. Some algal growth in channel bottom.
9	W 13th Rd. & Yellow River	7.83	12.60	Width: 95 ft., Depth: 3 ft., Velocity: 0.5 fps. Banks are lined with trees and vegetation. Some algal growths along channel bottom.
10	S. Olive Rd. & Yellow River	9.66	15.55	Width: 100 ft., Depth: 4 ft., Velocity: 2 fps. Banks are lined with trees and vegetation.
11	Peach Rd. & Yellow River	11.36	18.28	Width: 120 ft., Depth: 3 ft., Velocity: 2 fps. Banks are lined with trees and vegetation.
12	Redwood Rd. & Yellow River	13.45	21.65	Width: 81 ft., Depth: 4 ft., Velocity: 1.5 fps. Banks are lined with trees and vegetation.

*Water at all stations is mucky and yellowish brown in color. D.O. measurements are made from bridges, unless otherwise noted, and all width, depth, and velocity measurements are approximate.

The eleven combined sewer overflows are located from just upstream of Station 3 to just upstream of the Sewage Treatment Plant

FIGURE 9

SITE H-PLYMOUTH STATION LOCATION

Legend

1 Sampling Location
STP Sewage Treatment Plant
GS Stream Gaging Station

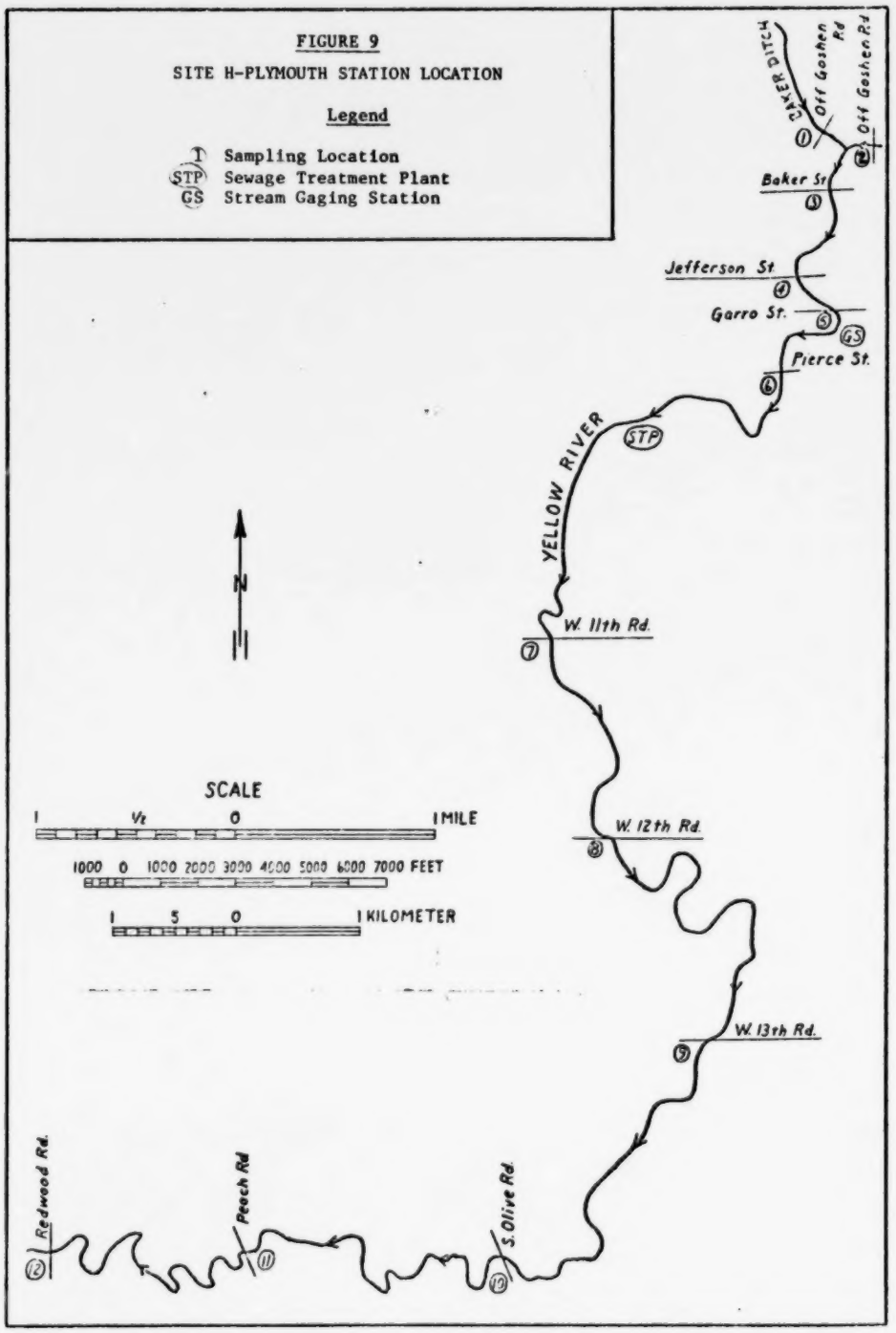

TABLE 19: DISSOLVED OXYGEN DETERMINATIONS FOR SITE H-PLYMOUTH

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	5/25/77 Dry Weather 10:15 am to 12:35 pm		5/31/77 Dry Weather 11:00 am to 1:00 pm		STORM II 6/5/77 After Rainfall 10:35 am to 11:40 am		6/14/77 Dry Weather 9:40 am to 11:30 am	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	8.1	17.8	9.4	17.2	7.1	18.5	7.6	15.5
2	6.2	19.0	6.8	19.0	6.3	17.3	5.2	15.8
3	5.8	19.6	6.4	18.9	6.6	19.0	6.6	15.8
4	6.0	19.2	7.7	19.0	6.4	17.3	7.3	15.9
5	5.4	19.5	-	-	6.5	18.5	7.1	16.0
6	5.3	19.9	7.1	20.0	6.6	18.0	7.8	16.0
7	4.3	19.4	6.1	19.0	4.9	17.0	6.3	15.9
8	4.0	19.1	-	-	5.1	18.0	5.6	16.2
9	4.8	20.0	-	-	6.3	17.8	6.2	15.6
10	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-

(continued)

TABLE 19 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	6/21/77 Dry Weather 2:00 pm to 4:10 pm		6/28/77 Dry Weather 2:15 pm to 3:45 pm		STORM III 6/29/77 After Rainfall 5:45 pm to 7:00 pm		STORM IV 6/30/77 During Rainfall 10:10 am to 11:30 am	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	9.6	19.9	8.2	21.7	7.7	21.0	8.2	17.8
2	7.2	19.7	6.1	21.5	6.8	20.5	7.6	19.0
3	7.9	19.5	6.7	21.0	7.2	20.4	7.7	19.0
4	7.2	19.2	6.7	20.8	7.1	20.6	7.7	19.1
5	7.5	19.3	6.5	20.6	6.8	20.7	7.5	19.5
6	7.2	19.8	6.4	20.6	6.9	20.4	7.8	19.5
7	5.9	19.0	4.8	20.2	5.2	20.8	6.4	19.6
8	5.7	19.0	5.8	20.0	4.6	20.0	6.3	19.2
9	6.0	19.4	5.4	20.1	5.4	20.0	6.6	19.0
10	-	-	-	-	-	-	-	-
11	-	-	-	-	-	-	-	-
12	-	-	-	-	-	-	-	-

(continued)

TABLE 19 (continued)

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	STORM IV 6/30/77 During Rainfall 5:20 pm to 6:22 pm		STORM IV 7/1/77 After Rainfall 1:20 pm to 3:00 pm		7/7/77 Dry Weather 1:40 pm to 3:45 pm	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	6.8	19.0	6.9	19.4	7.1	24.3
2	7.1	18.5	6.4	18.9	5.8	24.1
3	7.2	18.5	4.0	18.4	5.9	24.0
4	7.0	18.8	5.4	18.5	6.1	24.0
5	6.9	18.8	5.8	18.7	5.9	24.0
6	6.9	18.8	5.7	18.8	5.8	24.0
7	6.1	18.9	4.9	19.0	4.9	23.8
8	6.3	18.9	5.0	18.8	4.7	23.0
9	5.8	19.0	6.5	18.9	5.2	23.3
10	-	-	-	-	5.8	24.3
11	-	-	-	-	6.1	24.2
12	-	-	-	-	6.0	24.6

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Site I - Portland

Portland, the site most remote from Notre Dame and about 200 km (125 miles) southeast, had a 1970 population of 7,115. Seven combined sewer discharge points are located on the Salamonie River. A U.S.G.S. Gaging Station is located nearby.

The ten sampling stations shown in Figure 10 and described in Table 20 are convenient and nicely spaced to allow sufficient sampling. The quality of the water, in terms of D.O. levels, appears to improve as it moves through the town passing over shallow areas and through turbulent rapid areas. A significant drop in dry weather D.O. was observed at Station 7, shown in Table 21, and is likely due to the municipal waste discharges. Monitoring for the effect of combined sewer overflows may be difficult due to this apparently large organic waste load and the high reaeration rate caused by the shallow rapid areas.

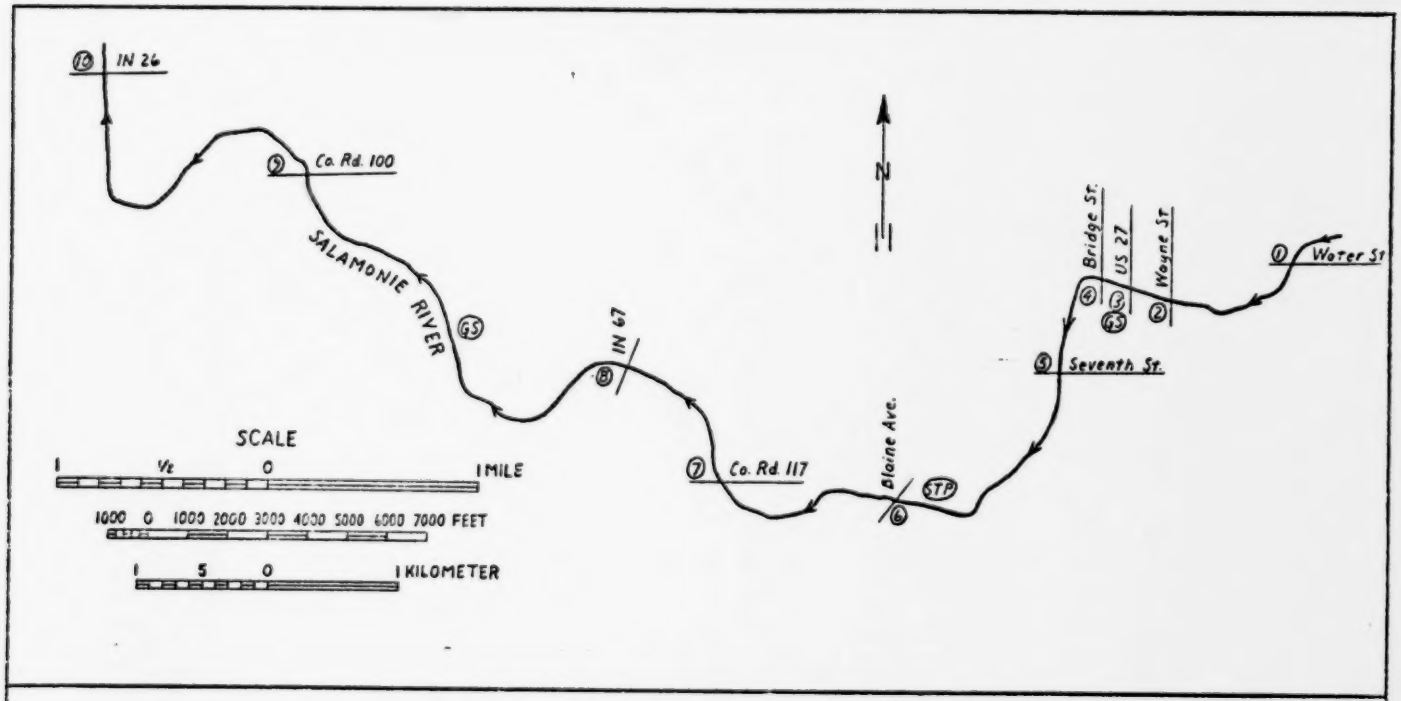

FIGURE 10

SITE I-PORTLAND STATION LOCATION

Legend

(1) Sampling Station Location
(STP) Sewage Treatment Plant
GS Gaging Station

TABLE 20: SAMPLING STATION DESCRIPTION

SITE I-PORTLAND

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
1	Water St. & Salamonie River	0	0	Width: 15 ft., Depth: 2 ft., Velocity: 2 fps. River bottom is silty and boulder strewn. No vegetation in the stream.
2	Wayne St. & Salamonie River	0.68	1.10	Width: 8 ft., Depth: 1 ft., Velocity: 2 fps. No vegetation in the stream.
3	US 27 & Salamonie River	0.87	1.40	Width: 10 ft., Depth: 1 ft., Velocity: 2 fps. Water is clear, with a boulder strewn bottom which forms a rapids under the bridge. Two 2-ft. diam. conduits are located under the bridge on the north side, and one 2-ft. diam. conduit is located on the south side. A 4ft. diam. conduit is located upstream on the north bank.
4	Bridge St. & Salamonie River	1.01	1.63	Width: 10 ft., Depth: 1 ft., Velocity: 2 fps. No vegetation in the stream.
5	Seventh St. & Salamonie River	1.54	2.48	Width: 6 ft., Depth: 1 ft., Velocity: 2 fps. An 8" conduit is located on the right, downstream side.
6	Blaine Ave. & Salamonie River	2.73	4.39	Width: 20 ft., Depth: 1 ft., Velocity: 0.5 fps.

(continued)

TABLE 20 (continued)

Station Number	Location	Cummulative Distance From Station 1		Remarks*
		Miles	Kilometers	
7	Co. Rd 117 & Salamonie River	3.67	5.91	Width: 20 ft., Depth: 1 ft., Velocity: 1 fps. A gravel pit and a food manufacturer are located upstream on either side of the stream. There are no visible effluents.
8	IN 67 & Salamonie River	4.43	7.13	Width: 20 ft., Depth: 1 ft., Velocity: 1 fps.
9	Co. Rd 100 & Salamonie River	6.75	10.87	Width: 15 ft., Depth: 1.5 ft., Velocity: 1 fps.
10	IN 26 & Salamonie River	8.55	13.76	Width: 15 ft., Depth: 1.5 ft., Velocity: 1 fps.

*The water at all stations is very muddy, with vegetation along the banks and in the stream, unless otherwise noted. All D.O. measurements were taken from bridges, and all width, depth, and velocity measurements are approximate. Right and left are defined facing downstream.

The seven combined sewer overflows are located from mid-way between Stations 1 and 2 to the Sewage Treatment Plant.

TABLE 21: DISSOLVED OXYGEN DETERMINATIONS FOR SITE I-PORTLAND

Dissolved Oxygen in mg/ℓ and Temperature in °C For Various Weather Conditions

Sample Station	8/11/77 Dry Weather 1:15 pm to 2:20 pm		STORM VII 8/11/77 During Rainfall 5:05 pm to 6:40 pm	
	DO(mg/ℓ)	Temp(°C)	DO(mg/ℓ)	Temp(°C)
1	5.9	23.0	5.2	23.0
2	7.3	24.0	7.0	23.0
3	8.5	25.0	7.2	23.0
4	8.5	26.0	7.1	23.0
5	9.9	28.0	6.3	23.0
6	11.0	28.0	6.3	25.0
7	4.7	28.0	4.1	24.0
8	-	-	3.5	24.0
9	-	-	3.9	24.0
10	-	-	4.8	23.0